Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 217 FEBRUARY, 1934 No. 2

SUPERAERODYNAMICS.

BY

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PREFACE.

The projected conquest of the stratosphere invites further research in the dynamics of tenuous fluids. In coursing the upper "isothermal" layer space craft and projectiles must obey new or modified laws of air resistance. These may well be studied in high-vacuum wind tunnels or chambers, under guidance of mathematical theory.

NEWTON'S STREAM OF DISCRETE PARTICLES.

A beginning of such theory was made by Sir Issac Newton.[1] Assuming a uniform stream of discrete particles, without mutual influence or pressure, he calculated its impact force on various hard smooth geometric forms. In general only particles perfectly elastic or perfectly inelastic, moving like a shower of shot through blank space, were considered.

The laws of resistance thence derived are absolutely valid for such a medium. But as they do not tally with the laws of natural fluids in usual conditions, they have found scant application. For highly rarefied gases however, even with the molecules moving in all directions, Newton's resistance formulas may not always be very far amiss. They may fairly apply

[1] Principia, Book II, prop. XXXIV, XXXV.

to a meteorite if not to a baseball. His premises may be summarized as follows:

1. The discontinuous rare medium consists of indefinitely small equal particles freely disposed at equal and great distances from each other; they may be elastic or inelastic, at rest or in uniform motion.

2. The particles, say in uniform rectilinear motion, strike only the front part of a fixed obstacle, leaving a vacuum behind extending to infinity, bounded by parallel streamlines grazing the body.

3. The particles striking the hard smooth front retain their tangential velocity component and lose their normal component, if inelastic, or have it reversed if elastic. In all cases before and after rebound they continue in straight lines without mutual interference: i.e. with substantially infinite free paths.

A brief application of these premises will be interesting.

RESISTANCE OF PLANE AND SPHERICAL SURFACES.

A smooth hard object of any form, fixed in a Newtonian stream, sustains at each surface element a normal pressure equal to the rate of mass impact times the change of normal velocity. The along-stream pressure component integrated over the front surface gives the resistance; the cross-stream pressure integral gives the transverse force; and their resultant is the total force.

In a flow having uniform speed and density v, ρ, a surface element dA, with inclination α to the stream, experiences the rate of mass impact $\rho v \sin\alpha dA$. The change of normal velocity is $v \sin\alpha$ for inelastic, $2v \sin\alpha$ for elastic particles. Hence the normal pressure per unit area is

$$p = \rho v^2 \sin^2\alpha, \qquad \text{or} \qquad p = 2\rho v^2 \sin^2\alpha, \tag{1}$$

and at normal impact $p = \rho v^2$ or $2\rho v^2$.

For elastic particles the pressure-force on the element is

$$dR = 2\rho v^2 \sin^2\alpha dA; \tag{2}$$

its components along and across stream are

$$dR_x = 2\rho v^2 \sin^3\alpha dA, \qquad dR_y = 2\rho v^2 \sin^2\alpha \cos\alpha dA. \tag{3}$$

Applying (2) to a flat plate gives for the resultant force

$$R = 2\rho A v^2 \sin^2 \alpha, \tag{4}$$

which expresses Newton's famous sine square law. It is perfectly valid for the assumed medium, and invites comparison with that for a somewhat similar natural medium, viz. a very tenuous gas.

To apply (2) to a sphere of radius a we note that

$$dA = 2\pi a \cos \alpha \cdot a d\alpha = 2\pi a^2 d(\sin \alpha);$$

hence $$R = 4\pi a^2 \rho v^2 \int_0^{\pi/2} \sin^3 \alpha \cdot d \sin \alpha = \pi a^2 \rho v^2; \tag{5}$$

or the drag of a sphere is half that of its major circle.

The foregoing text in substance summarizes Newton's doctrine of resistance in the assumed stream of discrete particles. His quaint proofs were devoid of symbols from trigonometry or infinitesimal calculus.

SOME EXTENSIONS OF NEWTON'S RESULTS.

Manifold applications of (1), (2), (3) are readily made. As illustrations let us compare the pressure and resistance of a few figures in a uniform Newtonian elastic-particle stream with those found in the air.

On a flat plate having inclination α to such a stream the rear pressure is zero; the face pressure is, by (1),

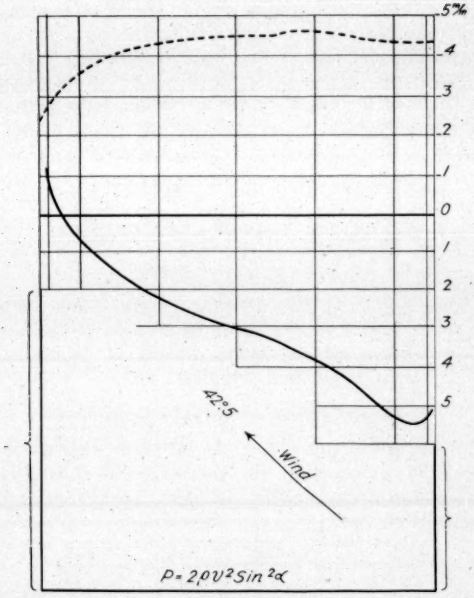
$$p = 2\rho v^2 \sin^2 \alpha.$$

This is uniform over the front, whatever the size, shape or inclination; it varies from 0 to $2\rho v^2$ as α increases from 0 to 90°; at fixed α the center of pressure is at the center of area.

For comparison we have in Fig. 1 a graph of Eiffel's [2] measured pressure at the median section of a square plate with $\alpha = 42.5°$, and of the constant face pressure computed by (1). Eiffel's graph shows a variable superstream pressure in front and a variable suction behind; the Newtonian pressure is constant $2\rho v^2 \sin^2 \alpha$ in front, 0 behind, yet furnishes a total air force exceeding Eiffel's. This is true for all large values of α.

[2] "The Resistance of the Air and Aviation."

FIG. 1.



Pressure on inclined plane for $\alpha = 42.5°$ as given by Eiffel for air, and by discrete-fluid formula $p = 2\rho v^2 \sin^2 \alpha$. Dotted line indicates suction on back of plate.

The greatest face pressure, as given by measurement and by Bernoulli's equation, is $\rho v^2/2$ at the stagnation point. In natural fluids such maximum-pressure points occur at various snclinations, especially at large angles; in the Newtonian itream they occur only at normal impact. Then p is double $\rho v^2/2$ for inelastic, quadruple for elastic particles.

The whole theoretical pressure-force for the plane area A is by (4)

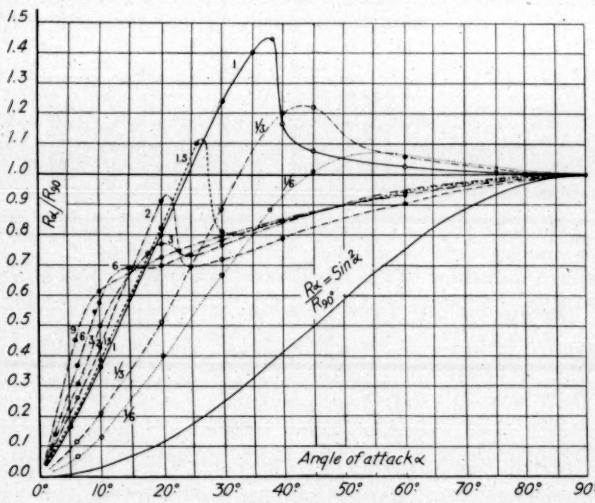
$$R = 2\rho A v^2 \sin^2 \alpha,$$

and does not vary with aspect ratio. At 90° this is $2\rho A v^2$; hence

$$R/R_{90} = \sin^2 \alpha,$$

R_{90} being the force at normal impact. This value is shown in Fig. 2 against Eiffel's values found in air. His graphs show that at small angles R increases with aspect ratio and directly as sin α. Hence the ensuing drag increases as $\sin^2 \alpha$, while the Newtonian drag increases as $\sin^3 \alpha$.

FIG. 2.



Values of ratio R_α/R_{90} for inclined rectangles of different aspect ratios, as found by Eiffel and by discrete-fluid formula $R_\alpha/R_{90} = \sin^2 \alpha$.

Many think Newton's inclined-plane formula (4) would preclude airplane flight. To test this opinion we compare the Newtonian values

$$L_c = 2 \sin^2 \alpha \cos \alpha,$$

$$D/L = \tan \alpha,$$

with Eiffel's wind tunnel values, at 10 meters a second, for a flat plate and a Wright wing, each measuring 90 × 15 cm., as follows:

Wing Coefficients.	By Newton's Formula.	By Eiffel's Measurements.	
		Flat Plate.	Wright Wing.
	$2 \sin^2 \alpha \cos \alpha$		
L_e at $\alpha =$ 0°	0.0000	0.000	0.147
3°	.0055	.109	.263
5°	.0152	.179	.326
10°	.0594	.338	.467
15°	.1295	.400	.554
20°	.220	.390	
30°	.4330	.400	
45°	.7071	.338	
	Tan α		
D/L at $\alpha =$ 0°	0.0000	∞	0.155
3°	.0524	0.230	.098
5°	.0875	.161	.10
10°	.1763	.20	.145
15°	.2679	.27	.25

These Newtonian coefficients for a flat plate do not indicate the unfeasibility of airplane flight. They show L_e large enough for taking off, and D/L more vaforable to high speed than Eiffel's values for either a flat plate or a Wright wing. So the critics of Newton's formula make two mistakes; first in saying it is disproved by experiment, second that it precludes flying. The table also indicates that the stratoplanist will be fortunate if, after climbing the troposphere by the sine law, he can finally cruise by the nearly sine square law well above the Piccard level.

A right cone, pyramid or wedge pointing up stream, in a Newtonian fluid, clearly has a uniform face pressure; also has a total drag

$$2\rho A v^2 \sin^3 \alpha = 2\rho B v^2 \sin^2 \alpha, \qquad (7)$$

where $B = A \sin \alpha$ is its frontal area, equal to the base area. For constant base and increasing sharpness the drag decreases to zero with α, the semi vertex angle. This property is not true of models in ordinary fluids subject to friction, though it may be fairly true of their pressure-drag alone.

For many models the Newtonian pressure declines from $2\rho v^2$ at the nose to 0 amidships. Such are struts, hulls, ellipsoids and other surfaces having planes or axes of symmetry along stream. As examples, Fig. 3 portrays the Newtonian

pressure on a round cylinder, Fig. 4 that on a sphere, in comparison with those found in a wind tunnel.

The drag on such models may by (3) be written

$$R_x = 2\rho v^2 \int \sin^3 \alpha dA. \tag{8}$$

For example, a round cylinder of radius a has, per unit length, $dA = ad\alpha$; hence integration over the front gives

$$R_x = 4a\rho v^2 \int_0^{\pi/2} \sin^3 \alpha d\alpha = \frac{8}{3} a\rho v^2. \tag{9}$$

This is 2/3 the drag of the cylinder's plane frontal area $2a$, and 4/3 that of a sphere of the same frontal area.

One easily applies (8) to various shapes of theoretic value in aeronautics; e.g. the elliptic cylinder, the prolate spheroid, the Rankine stream forms, etc. In continuous fluids these can have zonal [3] drag zero, positive or negative; in the Newtonian current the drag is always down stream at all parts of the model that sustain impact.

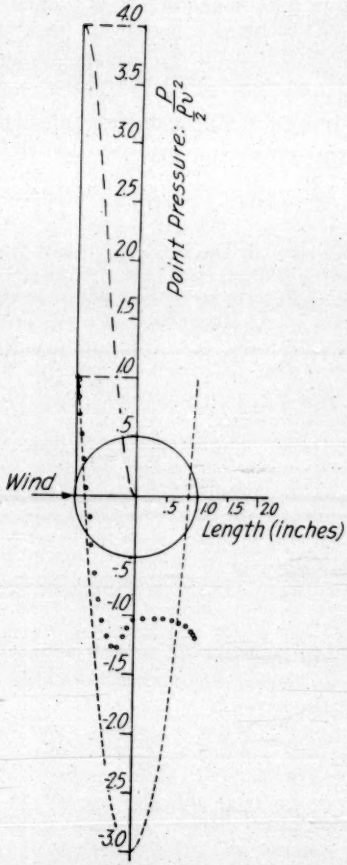
Interesting cases of upstream zonal drag are treated in Report No. 253 of the National Advisory Committee for Aeronautics. This shows that for an infinite inviscid liquid streaming uniformly, in any direction, past an ellipsoidal form, "the zonal drag is upstream on the fore half, downstream on the rear half, zero on the whole." Also it shows that the zonal pressure-drag in natural fluids may be upstream on the fore half of fair shaped ellipsoidal struts and hulls, though downstream on the whole model. Some recent experiments however indicate that the pressure-drag on a good form of airship hull may be negative not only for particular zones but also for the entire model.[4]

Besides results of some aeronautic application others of purely mathematic interest may be derived from the foregoing basic equations. For example many concave surfaces have the same reaction, though reversed in direction, in forward as in backward motion. Such are a shallow spherical cup with axis along stream, a hollow cone with $\alpha \geq 60°$, a thin

[3] A zone is the surface between the nose and any normal section.

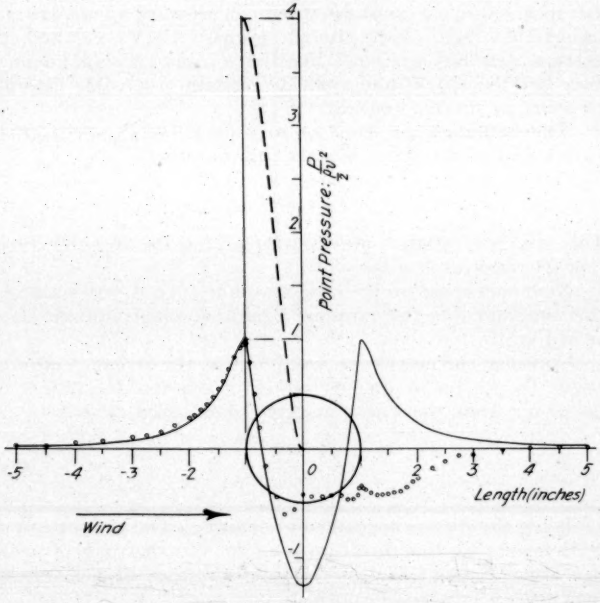
[4] Report No. 430, National Advisory Committee for Aeronautics.

FIG. 3.



Pressures on endless cylinder in different media.
— — Pressure in Newtonian Medium.
- - - - Pressure in Perfect Fluid.
. . . Pressure in Air.

FIG. 4.



Pressures on sphere in different media.
—— —— Pressure in Newtonian Medium.
—— —— Pressure in Perfect Fluid.
• • • Pressure in air.

arched airfoil, etc. These have less resistance than their frontal area because they deflect the particles obliquely. Conversely a hollow cone with $\alpha = 30°, 45°$, fixed with its open end upstream has the same drag as its frontal area, viz. $2B\rho v^2$, because all the particles after rebounding return along stream. Similarly a hollow parabola facing upstream has the same drag as its frontal area.

BOUNDARY PRESSURE WITH MOLECULES MOVING ALL WAYS SYMMETRICALLY.

Newton's quiescent particles, assumed free of applied forces can exert neither internal nor fixed-boundary pressure

nor move into a vacant space, made say by displacing a model. Let us give them a constant speed c in all ways symmetrically as in an ideal gas. Now, though stagnant as a whole, they can exert a boundary pressure, like that of any rare gas; even if they are too sparse and small to sustain a sensible internal pressure by mutual encounter.

The boundary pressure on any fixed body immersed in such a gas, of density ρ, has the known value

$$p = \tfrac{1}{3}\rho c^2.$$

This uniform "static" pressure integrated for any one direction has zero resultant.

Next superpose on the fluid a uniform speed, say v along x positive, and find the pressure against a plane normal to x, as in Fig. 5.

Consider the motion at any point of the stream taken as origin (x, y, $x = 0$) and as center of a reference sphere of radius a. Here the x-wise velocity of any particle is

$$v + c\frac{x}{a}, \tag{11}$$

x/a being the direction-cosine of vector c. The proportion of particles having this direction is $dx/2a$, viz. the ratio of areas of a zonal element and of the whole surface of the sphere. Hence the whole impact pressure is

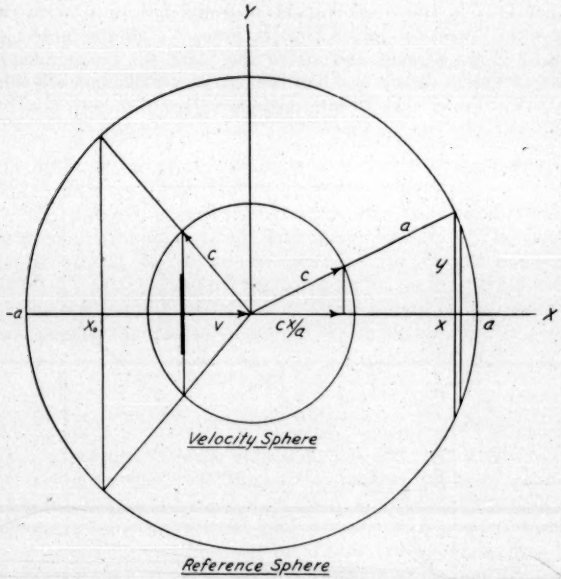
$$p = \int \rho\left(v + c\frac{x}{a}\right)\frac{dx}{2a}\cdot 2\left(v + c\frac{x}{a}\right), \tag{12}$$

the first factor representing the rate of mass impact of the particles whose c vectors have the direction-cosine x/a, the second factor denoting the velocity change of those particles at impact. For the down-stream pressure against the plane (12) gives

$$p = \frac{\rho}{a^3}\int_{x_0}^{a}(av + cx)^2 dx; \tag{13}$$

for the up-stream pressure we integrate from x_0 to $-a$.

FIG. 5.



Impact velocities of ideal-gas molecules against a fixed plane. Each particle has the x-wise stream velocity v and individual velocity c, with x-wise component cx/a, as shown. The proporton of particles having the direction whose cosine is x/a is $dx/2a$, viz. the ratio of the area of a zonal element to the whole area of the sphere with radius a.

I. For $c = 0$, clearly $x_0 = -a$; hence (13) gives

$$p = 2\rho v^2,$$

as for the simple Newtonian stream.

II. For $v = 0$, $x_0 = 0$; hence

$$p = \tfrac{1}{3}\rho c^2,$$

which is the "static" pressure of an ideal gas.

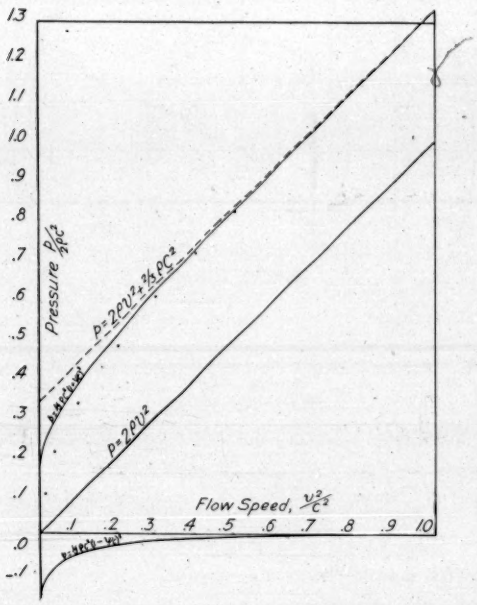
III. For $v \geq c$, $x_0 = -a$; hence

$$p = 2\rho\left(v^2 + \frac{c^2}{3}\right) \qquad (14)$$

which is a straight line in the coördinates of Fig. 6. One notes that (14) is the mass impact pressure $2\rho v^2$ plus twice the "static" pressure $\frac{1}{3}\rho c^2$. That is, for $v \geq c$ all the molecules move down stream and strike the plane on the windward side, whereas for $v/c = 0$ half the particles strike on each side.

IV. For $0 < v < c$ intermediate values of p, both positive

FIG. 6.



Pressure graphs for the face and back of a plane fixed normal to a stream of uniform molar speed v and molecular speed c. The upper and lower curves graph respectively the face and back pressures; their algebraic sum is the resultant pressure per unit area, outlined by the dots.

————	Plate	25	× 25	aspect ratio	1.
– – – – – – – –	"	22.5	× 15	" "	1.5.
– . – . – . – .	"	30	× 15	" "	2.
– .. – .. – .. –	"	45	× 15	" "	3.
...–...–...–...–	"	90	× 15	" "	6.
..–..–..–..–..–	"	90	× 10	" "	9.
...—...—...—	"	15	× 45	" "	1/3.
.....	"	15	× 90	" "	1/6.

and negative, occur. By (13) the positive pressure is

$$p = \tfrac{1}{3}\rho c^2 \left(1 + \frac{v}{c}\right)^3, \tag{15}$$

and the negative is

$$p = -\tfrac{1}{3}\rho c^2 \left(1 - \frac{v}{c}\right)^3; \tag{16}$$

the limits of integration being from $-av/c$ to a for (15) and from $-av/c$ to $-a$ for (16).

Fig. 6 shows, in convenient coördinates, the various values of p, positive and negative, and their resultant. The curve (15) begins at (0, 1/6) and merges with the straight line (14) at (1, 4/3); the curve (16) beginning at (0, $-1/6$) merges with the zero-pressure line at (1, 0). The resultant of the positive and negative pressures, or sum of (15) and (16), is

$$p_r = 2\rho c^2 \left(\frac{v}{c} + \frac{v^3}{3c^3}\right),$$

whose graph is outlined by the dots; it begins at (0, 0) and at (1, 4/3) merges with the graphs of (14) and (15).

To apply these equations to an inclined plane or surface element, having the angle of attack α, one changes v to $v \sin \alpha$. Thus in Fig. 1 the "perfect-gas" pressure p, if plotted, would show a constant value given by (14) or (16) on changing v to $v \sin 42.5°$; in Fig. 3 it would vary from a maximum at the nose to a minimum at the sides, and given by these same formulas. In Fig. 5 also $v \sin \alpha$ would replace v.

A body in translation through such a gas sustains no pressure on any rear element for which $v \sin \alpha > c$. Thus there may be a perfect vacuum immediately behind and keeping pace with the body, though not extending far to the rear. For example, a meteorite may for an instant be white hot on its forward skin, due to air impact, yet intensely cold on its rear skin as well as throughout the interior.

CONCLUSION.

The foregoing few examples of reactions in rare fluids may serve for test cases. If, for instance, Eiffel's inclined plane measurements be repeated in a high-vacuum wind tunnel, at

lower and lower pressures, a shift of his graphs toward the lower one in Fig. 2 should eventually become perceptible. Again pressure measurements on a sphere or cylinder should show a tendency to eliminate the marked negative values on the forward part.

Experimental check of the foregoing formulas may therefore be recommended for academic research. A further task is to find equations for the reaction of a fluid whose particles have moderately long finite free paths instead of the usual very short ones or the infinitely long ones assumed by Newton. Also, as a natural body surface is not perfectly smooth it may lessen the tangential velocity component, thus introducing an added element in the equations for the surface reaction. The nature of this surface damping has been studied by Maxwell,[5] Millikan [6] and others.

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[5] Scientific Papers, Vol. II, p. 705.

[6] "Coefficient of Slip in Gases, etc.," *Phys. Rev.*, March 1923.

ABSORPTION MEASUREMENTS OF THE COSMIC RADIATION.

BY

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Communication No. 85.

Notwithstanding more than twenty years of experimental investigation of the cosmic radiation, seven of which have been years of intensive activity, we are still wondering where these rays come from, how they are produced and, in fact, whether they consist principally of waves or of corpuscles. In view of the remarkable development in knowledge of the structure of the atom which arose out of the spectroscopic determination of the energies of the characteristic radiations, it is natural that we should look again to energy determinations as the most promising key to the solution of the present mystery. Energy, in one form or another, is a quantity which we feel must be conserved and if it appears in the form of the cosmic radiation equal amount must have been given off during some kind of a quantum transition. The possibility of interpreting the cosmic radiation in terms of quantum transitions was first realized in 1928 through the highly interesting speculations of Millikan and Cameron which were based upon their measurements of the absorption of the rays.

If the atmosphere were compressed to the density of water its depth would be approximately ten meters. By carrying their instruments up in airplanes and on mountain tops and by sinking them down in lakes they succeeded in observing the intensity over a range of depths extending from about six meters to eighty meters below the top of the atmosphere. The resulting intensity-depth curve had the general appearance of an exponential, but it was found to deviate from the simple form of this law even when all-sided incidence of the radiation at the top of the atmosphere was taken into account. They did find, however, that the curve could be analyzed as

the sum of several such simple exponential functions, each of a different coefficient. Each term of this sum they supposed to arise from a distinct component of the radiation and from the absorption coefficients they deduced the energies. This deduction was made with the aid of the theoretical formula of Klein and Nishina which is based upon Dirac's theory of the interaction between hard gamma rays (it being supposed that the cosmic rays were of this nature) and the free electrons in the absorbing material. In looking for possible energy levels, transitions between which would account for the deduced energies, they were led to the atom building hypothesis as the only possibility. Thus the observations of the cosmic radiation seemed to give a definite picture of a creative process which formed the basis for a theory of cosmic evolution.

Following upon this early work, more accurate and more extensive measurements of the absorption have been made, both by Millikan and by Regener with their respective coworkers, the most recent of which have been reported within the past few months. Now both schools have measurements extending from within a fraction of a meter (water equivalent) of the top of the atmosphere to depths of water at which only a minute trace of the radiation persists and the accuracy of these measurements is best indicated by the fact that the two schools are in substantial agreement.

From the results of this later work, as of the earlier work, it is evident that the radiation consists of distinct components of widely different penetrating powers. This fact is perhaps most impressively realized from an analysis made by Lenz. The measured cosmic ray intensity, i.e. the ionization produced in a closed vessel at constant pressure, is multiplied by the atmospheric pressure at the corresponding elevation. The resulting function of elevation is thus proportional to the rate of production of ions per unit volume in the free atmosphere, and although nothing new has been added, this procedure levels the intensity curve so that its irregularities become more apparent. Instead of the continuously rising slope of the intensity curve, the transformed function displays a sharp maximum at a depth of 1.6 meters below the top of the atmosphere and other humps are evident at other depths.

In fact the appearance of the curve is not unlike that of the densitometer trace of a poorly resolved multiplet. Quite irrespective of all assumption as to the nature of the radiation or the process of its absorption these humps may be supposed naturally to correspond to the penetrations of the various components of the radiation for it is highly improbable that either a homogeneous radiation or a nonhomogeneous radiation homogeneously distributed in energy, could produce the observed irregularities.

If some assumption is made as to the form of the absorption law then the coefficients for the various components may be deduced, using either the position of the humps of the distorted curve of Lenz, or, just as well, the absorption curve itself. In carrying out the analysis Millikan's school have clung to the exponential law taking account, of course, of all-sided incidence at the top of the atmosphere. Strictly, this law applies only to those absorption processes in which the primary ray loses no energy until it reaches some point where, by collision, or rapid degradation in a very short space, it loses all of its energy suddenly. Regener's school, on the other hand, seeks to take account of a prediction, based upon the theory of the Compton effect, that secondary rays are generated when the primary gives up its energy, and these secondary rays have ranges comparable with, though not as great as, the range of the primary ray. Such a situation is to be expected if the absorption is that of a gamma radiation experiencing Compton encounters with the free electrons of the absorbing material. On the other hand, if the absorption is principally nuclear, a more rapid degradation of energy may be expected and the situation would approach that described by the exponential law. Therefore, if the primary radiation is a gamma radiation, these two assumptions represent the opposite extremes of the possible types of absorption laws. For this reason it is interesting to compare the coefficients which result respectively from the two analyses. These are contained in Table I.

It is true that the taking into account of the secondaries has resulted in slightly higher coefficients for the most penetrating primary components, but it is remarkable how slight the differences are in the actual results in spite of the differences in the assumed absorption laws.

TABLE I.

Absorption Coefficients of the Four Principal Components of the Primary Cosmic Radiation Expressed in (Meters of Water)$^{-1}$.

Bowen, Millikan and Neher (exponential law)	0.015	0.06	0.12	0.55
Kramer and Lenz (account taken of secondaries)	0.0209	0.075	0.16	0.52

Except for a gain in accuracy and the extension of the range of the observations, neither the absorption curve nor its analysis into components has changed appreciably since 1928, for the absorption coefficients given by Millikan and Cameron at that time agree closely with those given above in the table. But the situation in regard to the translation of absorption coefficients into energies is different. The original use of the Klein-Nishina formula involved an extrapolation far beyond the energy range in which the formula had been tested, and although this was dangerous, as Millikan has himself pointed out, there was no definite reason to suspect an error. Recent developments, however, have shown, not only that the absorption is not entirely due to Compton encounters with free electrons, as the Klein-Nishina formula supposes, but that nuclear processes are involved and, in fact, newly discovered particles, the positive electron and the neutron, also play a part. Until the interaction of the radiation with the nucleus is better understood, it will be impossible therefore to make any satisfactory interpretation of the derived absorption coefficients.

With the reservations of this statement in mind we may now call attention to a fact pointed out by Jeans and, again recently, by Regener that if the nuclear electrons are considered as being free with respect to the two most penetrating components, the Klein-Nishina formula gives energies for these components in agreement with those which would be produced respectively by the conversion into radiant energy of the mass of the alpha particle, and the mass of the proton. The difference in the masses of four hydrogen atoms and one helium atom can then account for the softest component as originally suggested by Millikan and Cameron. In the present status, however, deductions such as these are premature and are only to be regarded as indications of the type

of results which may be in store to reward such investigations as will eventually lead to a satisfactory relation between energy and the absorption of the radiation.

It is of primary importance for this development that we discover, first of all whether the primary radiation is corpuscular or of a wave character. The form of the elementary absorption function may not be far different for the two cases, but one can hardly expect the relation of energy to absorption to be independent of the character of the radiation. If the primary radiation is corpuscular as we know is the case for at least a part of it, the energy selection provided by the magnetic field of the earth should provide a means for directly determining the relation between energy and absorption within a narrow range of energies. If the absorption curves are found for different latitudes their differences should lead to the absorption characteristics of the component which is present at the higher latitude but absent at the lower latitude. The energy of this component is determined, of course, by the latitude. Still narrower ranges of energy can be focused upon by carrying out the experiment at a definite angle with the use of a train of counters instead of the usual electroscope.

Information which will eventually form the basis for an exact absorption theory should also result from a continuation of the cloud chamber experiments of Anderson, Kunze, Locher, and Blackett and Occhialini, as well as from other types of investigations dealing with secondary effects. High voltage experiments dealing with nuclear processes are also shedding light upon the mechanism of energy loss by rays of energies approaching those which are observed in cosmic ray phenomena. With the many possibilities at hand for extending our knowledge of the absorption process, any interpretation of absorption coefficients of the cosmic radiation at the present time would be premature. On the other hand those working on cosmic ray investigations will welcome the results of the intensity measurements as a solid nucleus of the rapidly developing body of experimental data which will eventually yield to a consistent interpretation. That the final interpretation will be interesting and far reaching in its consequences is not to be doubted.

Why Vehicles Pass On Right.—(U. S. D. A. Clip Sheet No. 806.) The Conestoga wagon, the freight-hauling vehicle of the early days, is responsible for the present custom of vehicles passing on the right in the United States, according to the Bureau of Public Roads. Before the extensive use of the Conestoga wagon it was customary to pass vehicles to the left, following the earlier English rule.

In England in the days when men traveled armed on horseback, it was the custom to pass to the left so that the sword or pistol arm would be on the side of the man passed. Later, in travel by coach or wagon, the driver sat on the right side to give his right arm free play in wielding the whip, and passing to the left he was better able to avoid entanglements with the wheels of passing vehicles.

On the Continent—in France, Germany, and Italy—the postillion system of driving, by which the driver sat on the left wheel horse, existed in the early days for both coaches and wagons. In these countries, passing to the right has always been the custom.

In Italy until the time of Mussolini vehicles in the city, where postillions were customary, passed to the right; in the country, where box wagons were much used, vehicles passed to the left. Mussolini made passing custom uniform by decreeing that all should pass to the right.

The drivers of the Conestoga wagons rode the left wheel horse and passed to right as a matter of convenience although it was then contrary to custom. These wagons also were fitted with a "lazy board"—a board between the two left-side wheels that pulled out and could be ridden when driving from the side of the wagon. These drivers found that passing to the right was much to be preferred.

C.

The Tomato—A One-Way Affair?—S. MUSGRAVE, in a note to *Chemistry and Industry*, tells about cutting an unripe tomato in half perpendicular to the stem; placing the two halves close to each other, and the whole left to ripen. After about a week the upper half, containing the stalk end, had ripened to a good red color, while the lower half remained its original green. The tomato was frequently moved, so there could be no question of light falling unevenly on the two sides.

C.

THE HEAT OF DISSOCIATION OF Bi_2 DETERMINED BY THE METHOD OF MOLECULAR BEAMS.

BY

CHENG CHUAN KO, Ph.D.

ABSTRACT.

Using the velocity analyzer of Zartman with improved technique the combined velocity spectrum of Bi atoms and Bi_2 molecules was obtained at 827°, 851°, 875°, 899°, 922°, 947° C. From the spectral distribution curves the relative abundance of Bi atoms and Bi_2 molecules in the beams at the above temperatures could be determined to 1 per cent. The vapor pressure curve of Bi was obtained experimentally by the method of effusion and the values so obtained were combined with the degree of dissociation of the vapor as computed from the beams to give the heat of dissociation. The heat of dissociation was computed from the data, assuming the pressure to be given by the temperature of the crucible T_c. In calculating the heat of dissociation, the equilibrium temperature was taken as that of the slit chamber T_s which was 24° above T_c. The results of these calculations plotted with $\log_{10} K_p$ as ordinates against $1/T_s$ give a straight line whose slope yields the value of the heat of dissociation as 77,100±1200 calories. The curves for the distribution of velocities observed and computed on the assumption of a given ratio of Bi atoms to Bi_2 molecules in the beam were compared in an attempt to test the law of distribution of velocities. On the high velocity side agreement in two curves was obtained within the limits of experimental accuracy. On the low velocity side important deviations were noted of such a sort that the observed curves below a velocity $\alpha/2$, (α is the most probable velocity) gave *more* molecules than the theory demanded. Other deviations were observed on some of the runs taken with a fourth slit in which a deficiency of molecules was observed between velocities of $.75\alpha$ and $\alpha/2$. This deviation was probably due to a warping of the fourth slit carriage due to heat. The nature of the variation at velocities less than $\alpha/2$ indicated the presence of molecules of greater mass than Bi_2 in the beam and at the lower temperatures a distinct peak corresponding to Bi_3 molecules was observed which were present to less than 2 per cent. The vapor pressure curve for Bi was determined by least square reduction of the observed points to be given by $\log_{10} P = -52.23 \times \frac{195.26}{T} + 8.56$ between 1100° and 1220° abs. It lies very close to the extrapolated curve given in the International Critical Tables.

INTRODUCTION.

In 1930 I. F. Zartman [1] developed a molecular beam velocity analyzer designed by E. E. Hall to a point where good velocity spectra of Bi some 30 mm. in length could be ob-

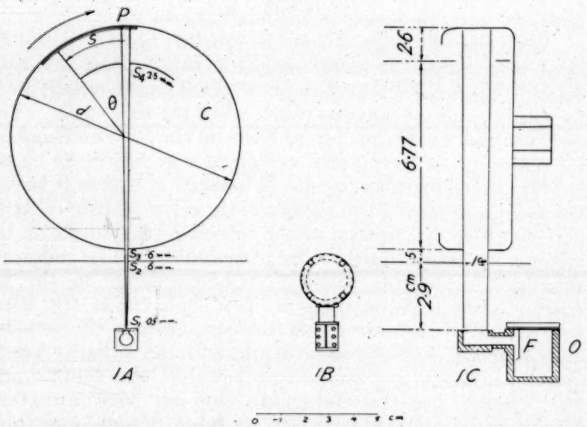
tained. These spectra at once showed that the beam consisted of atoms of Bi and molecules of Bi_2 whose relative proportions varied with the temperature of the source. In his paper Zartman indicated the possibility of using the relative abundance of Bi and Bi_2 particles in the beam to determine the heat of dissociation of Bi_2. Contemporaneously with Zartman's work, Alfred Leu,[2] in Stern's laboratory, used the effect of a divergent magnetic field on a molecular beam to separate the Bi and Bi_2 particles and from the variation of the composition of the beam with temperature, calculated the heat of dissociation of Bi_2. As Fraser [3] has shown in his book entitled "Molecular Rays," Leu neglected certain factors in his calculations and so arrived at incorrect values. Fraser recalculated Leu's results, eliminating some of the errors, and in doing so unfortunately a blunder crept into the calculation which made his value wrong by a factor of 2.303. The present work is primarily an attempt to develop Zartman's method to a point where a good evaluation of the heat of dissociation can be obtained. It was further hoped to verify the Maxwell distribution law by a comparison of the observed distribution with that computed from an assumed concentration of Bi atoms and Bi_2 molecules in the beam. The investigation was begun in collaboration with F. F. Coleman. On his departure to take up a Rhodes Scholarship, the writer carried the problem on alone and brought it to a conclusion. As will be seen, the primary objective was achieved with some measure of success. The verification of the distribution law was not as satisfactory as was hoped for. Part of this difficulty lay in a certain phase of the technique which can in the future be remedied. Another part of the difficulty, however, lay in the fact that together with Bi and Bi_2 there was present at the lower temperatures another molecular form of Bi, to wit Bi_8. It was therefore decided that the verification of the distribution law by this method requires the use of a *monatomic* beam and cannot be had with Bi. While this work was in progress, the admirable study of the distribution law for *K* and *Li* by Meissner and Scheffers,[4] using the magnetic method, has given an accurate verification of the distribution law for the lower velocity range.

THE METHOD.

Since the method followed is essentially that used by Zartman, much of the description of the apparatus and procedure will be omitted in the cause of brevity. Accordingly only such items will be presented as indicate improvements or radical departures from the method already reported in detail by Zartman.

In principle the method is illustrated in Fig. 1. Figure 1*A* shows a front view of the apparatus. At the bottom is a

FIG. 1.



crucible of which a view from above is shown in Fig. 1*B*. This crucible has a slit S_1 (the crucible slit) of aperture varying from 0.05 mm. to 0.09 mm., length 10 mm., and depth 0.02 mm. and at times 0.2 mm. In this crucible the Bi vapor was maintained at a pressure ranging from 0.2 to 2.0 mm. Hg, depending on the crucible temperature. S_2 constituted an image slit of width 0.6 mm. and length 10 mm., parallel to S_1. Its width in an actual run of from 5 to 20 hours gradually decreased to 0.3 mm., due to the choking up of the slit by a

deposit of Bi atoms which could not be avoided. The cylinder C, 9.4 cm. in diameter, of high speed steel, had a slit S_3 0.6 mm. wide and 1 cm. long on its lower edge. Diametrically opposite this was rigidly clamped a thin glass plate P, bent to the curvature of the cylinder and coated with a thin uniform deposit of Bi atoms. In some of the runs a fourth slit, S_4 width 2.5 mm. and length 10 mm., was mounted on a brass frame clamped to the structure containing S_2. A side elevation of the crucible and cylinder is shown in Fig. 1C, where the crucible is labelled O. The cylinder could be rotated at a speed of 30,000 R.P.M. about its axis (in a clockwise direction) by means of the shaft shown.

With the slits aligned and the crucible heated to the desired temperature an electromagnetic shutter just below S_2 could be opened for a minute or two enabling a deposit to be formed below P on the glass plate, called the zero mark. This fixed the width of the molecular beam on the plate and enabled its center to be accurately evaluated. A fine hole in the cylinder diametrically opposite S_3 assisted in this as it gave a fine point deposit of Bi on the back side of the plate in rotating past S_2 which can be seen at the top of the zero mark in the microphotometer records. The plate could then be removed, stabilized by heating to 60° C., photometered on the recording Zeiss microphotometer, and replaced in the same position. The apparatus was then evacuated, the crucible heated to the desired temperature, and the cylinder set in rotation. When conditions were suitable, the shutter was then opened and the molecular beam set into operation. After 5 to 20 hours, the molecular beam deposit was thick enough for study. The run was then terminated, the apparatus opened, and the glass plate removed and again photometered.

DETAILS OF THE APPARATUS.

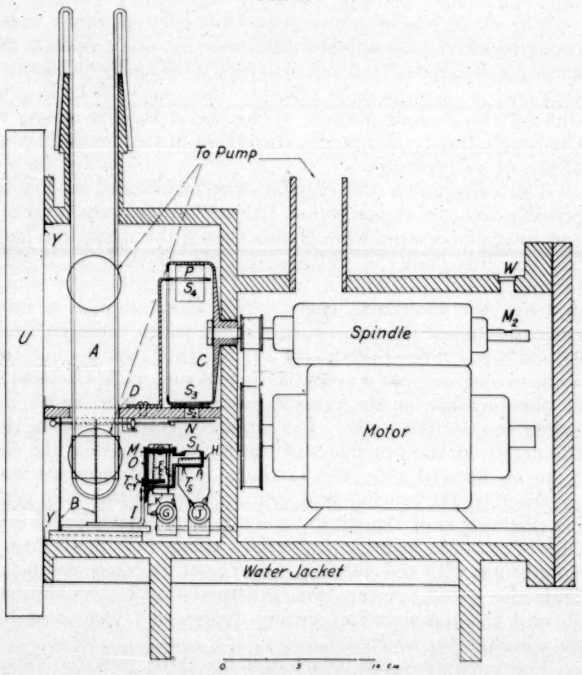
The whole assemblage as used is indicated in Fig. 2 which is a vertical cross-section through the axis of the cylinder and is self-explanatory. Details of the various parts which differed from those used by Zartman follow.

The crucible is essentially of the form used by Zartman. It was machined out of carbon steel which serves well for Bi. It was tried in the case of Sb which, however, attacked it so

badly that high speed tool steel was needed for this substance. Its evaporating surface was 2 cm.², which is about 220 times the slit opening, insuring equilibrium in the crucible with evaporating Bi.

The crucible was provided with a side tube having a channel 2 cm. long by 0.5 cm. in diameter, which carried the slit on its upper face. This together with a thin steel baffle plate, *F*, Fig. 2, prevented the sputtering of the boiling Bi metal from interfering with the molecular beam. Thermocouples were imbedded at both ends of the slit chamber and in

FIG. 2.



the base of the crucible adjoining the boiling metal. A thin mica gasket between the crucible cover and the crucible was found essential to prevent the crucible cover from being soldered to the crucible. The crucible was heated by radiation from three 100 watt tungsten filaments and the conduction from the slit and the filaments was so arranged that the slit chamber was in all but one run maintained 24° C. above the crucible to prevent the choking of the slit by condensation of Bi. The crucible was so mounted that it could be removed and weighed between the formation of the initial deposit and the final run without altering the alignment of the slits.

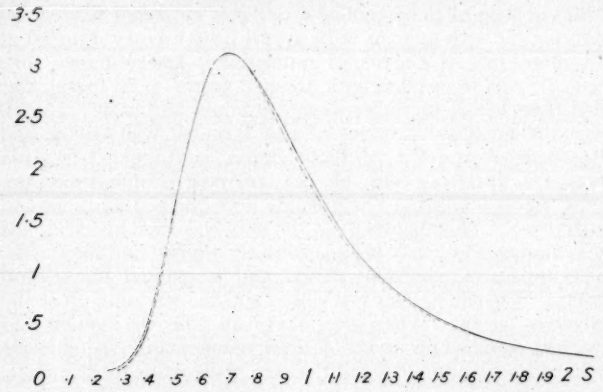
The slit S_1 was in some cases a knife edge slit whose width could be altered by adjusting screws. At other times a slit having a thickness of 0.2 mm. was used as Clausing [5] has shown that such a beam is more efficient than one with knife edge slits for the present purpose. The use of this, according to Clausing's theory, required a correction in the determination of the vapor pressure.

The pressure in the crucible was maintained as low as possible, in order to maintain a true molecular beam. Stern [6] and his collaborators have shown that if the mean free path becomes less than the width of the slit, there is a "cloud" formation immediately in front of the crucible slit which destroys the molecular beam. This cloud formation in a measure limited the temperature range which could be studied, as below a temperature of 827° C. the beam became too weak to measure in a reasonable time of run, while above 947° C. the pressure in the crucible exceeded 2 mm. which required too narrow a slit. The large evaporating area of the Bi surface in the crucible and the large aperture of the slit chamber insured that the pressure P in the crucible was governed by the crucible temperature, T_c. At the same time the dimensions of the slit chamber and its entrance and exit (slit S_1) orifices insured the vapor coming into temperature equilibrium with the slit chamber walls at T_s before escaping. Thus the vapor pressure was governed by the temperature T_C and the temperature causing dissociation was given by the slit chamber as T_s.

The apparatus was evacuated by three mercury vapor

pumps as in Zartman's case. Added vapors were condensed on a liquid air surface A, Fig. 2, inserted into the cylinder compartment. Vanes B in contact with A, and projecting downwards about the filaments and crucible, aided in removing the excess heat from the filaments and protecting the heavy glass plate V covering the front of the apparatus. In addition the crucible and filaments were screened by a double walled shield of nickel. This shield reflected enough of the filament radiation back to the crucible to raise it to 1000° C. while in its absence, 850° could hardly be reached. Finally to remove heat from the assemblage, a water cooling system surrounding a large part of the housing was provided.

FIG. 3.



When the apparatus was in operation, the three pumps managed to maintain a pressure of 10^{-5} mm. Hg as indicated by McLeod gauges. This of course did not give the true pressure as the evaporating Bi and some condensible vapors from the heated metal parts (at about 50° in the cylinder chamber) were not measured by the McLeod. It is believed that with the modern Apiezon pumps and an ionization gauge, improvements in the vacuum actually existing can be achieved; and that at times in the past the residual condensible mole-

cules present were the cause of the slight diffusion of the molecular beam which proved troublesome.

The temperatures were read on the chromal-alumal thermocouples inserted into the crucibles as shown in Fig. 2. These were calibrated in terms of a standard Pt-PtRh thermocouple and read by potentiometer to within 3° C.

The speed of the rotating cylinder was determined and maintained constant precisely as described by Zartman, a stroboscopic method with standardized tuning fork being used. The speed used in most runs was closely 120.7 revolutions per second.

PROCEDURE OF A MEASUREMENT.

After the curved glass cover slide had been coated with a uniform layer of Bi by cooling it to liquid air temperatures and sweeping it with a beam of Bi atoms from an oven rotated at a uniform rate, it was placed in position in the cylinder. The crucible was then filled with about 8 grams of Bi metal that had been boiled in vacuum several hours and cast. The Bi was the analyzed product of the Powers, Weightman and Rosengarten and Co. of Philadelphia, containing 0.005 per cent. Cu, 0.007 per cent. Fe, 0.02 per cent. Pb, and 0.04 per cent. Ag as labeled. The crucible was weighed and inserted into place. The alignment of the slits was then checked, the slits having previously been accurately aligned and measured. The apparatus was next closed and evacuated for several hours. The slit shutter was closed and the warming up of the crucibles begun. When after about an hour the system had reached equilibrium at the desired temperature, the slit was opened for two minutes and the zero mark made on the plate, the proper density being determined by visual observation through *V*. After the apparatus had cooled down, air was admitted and the time of the procedure recorded. The glass plate with initial deposit and zero mark was then removed and heated to 60° C. for about 10 minutes. It was then microphotometered. The microphotometer record was made with a magnification of two to one and fiducial marks for zero intensity and full intensity of the light source were made at each end of the plate. The glass plate was then replaced in the cylinder. The crucible was removed and weighed and its

loss of weight recorded. This loss of weight during the two or more hours of warming up and cooling down was a correction to be subtracted from the loss of weight in the long runs, which were used in measuring the vapor pressure. After weighing, the crucible was replaced, the apparatus sealed, and evacuation begun.

The short heat treatment stabilizing the initial deposit and zero mark was found to be the solution to the whole difficulty encountered by Zartman and Coleman which appeared to consist of a change in this deposit after photometering and before the final record was made. There was distinct evidence in the work of the previous investigators that the deposit crept over the surface and evaporated somewhat between the first and second photometerings. It was found to be due to the fact that in the long run, the whole cylinder heated up to about 50° C. As the previous deposits had never been heated above room temperature, and one was made at liquid air temperatures, the deposit required heating to a temperature slightly above that reached by the cylinder, for stabilization, before measurement.

The motor was then set into operation, the filaments were heated and the actual run was started. After temperature equilibrium was reached and the apparatus had steadied down, the slit S_2 was uncovered and, depending on the vapor pressure used, the run was continued for 5 to 20 hours. The run could be interrupted at will, the apparatus cooled down and the deposit examined to see if it appeared thick enough. After the run, the plate was removed and photometered as soon as possible. In photometering it, the scale of enlargement was accurately fitted to the previous scale and the source intensity was adjusted so that the fiducial intensity marks in the first plate coincided exactly with those on the second plate. The crucible was then removed and weighed to give the data needed for determining the vapor pressure during the run.

THEORETICAL CONSIDERATIONS AND CORRECTIONS.

Had the molecular beam consisted of molecules of an unique velocity v and had the beam been infinitely narrow, a zero mark displaced to the left of P, Fig. 1, would have been observed. The displacement S would have been given by

$S = (\pi d^2 n/v)$ where d is the diameter of the cylinder and n is the frequency of rotation. Actually the molecules are assumed to be distributed according to Maxwell's distribution law which says that the number N_v of molecules of velocity v in the beam is

$$N_v = \frac{2N}{\alpha^4} v^3 e^{-(v^2/\alpha^2)}\, dv$$

as they escape through a slit. Hence if only one species, say Bi, were present, the single line would be spread out in a "spectrum" along S, each S corresponding to a given value of v given by $v = (\pi d^2 n/S)$. In writing the equation in terms of S the most probable velocity α must be replaced by the distance of the displacement S_α of the most probable velocity which is given by the relation $\alpha = (\pi d^2 n/S_\alpha)$ and $\alpha = \sqrt{2kT/m}$, where k is the Boltzmann constant, T the absolute temperature, and m the molecular mass. Actually, as Stern [7] has shown, a finite slit of half width a necessitates a correction to this law such that the ratio of the number N caught at S to the number N_0 in the initial beam is

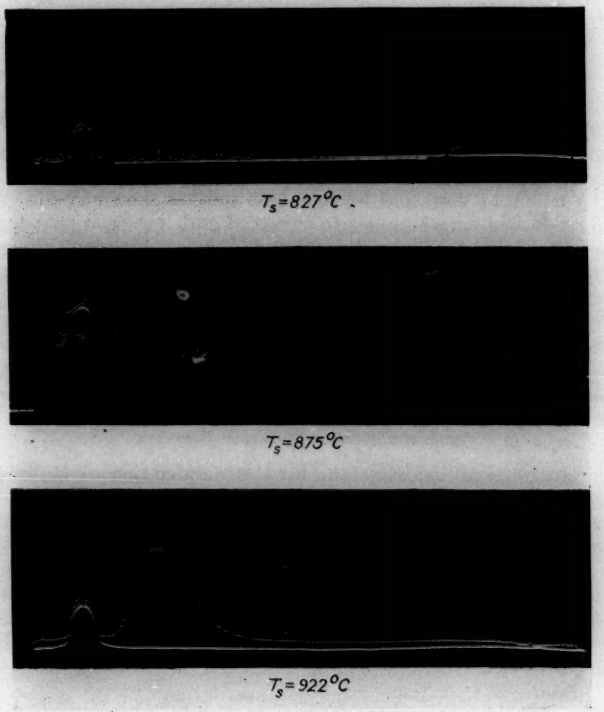
$$\frac{N}{N_0} = e^{-[S\alpha/(S+a)]^2}\left[\left(\frac{S\alpha}{S+a}\right)^2 + 1\right] - e^{-[S\alpha/(S-a)]^2}\left[\left(\frac{S\alpha}{S-a}\right)^2 + 1\right].$$

This law assumes that the zero mark deposit is of uniform density over its whole width from $S = -a$ to $S = +a$; that the shape of the zero mark is a narrow rectangular image; that the width of the zero mark is small compared with the value of S_α, and that the width of the slits does not change during the run, thus changing the width of the zero mark.

The shapes of the zero marks indicate that in conformity to the geometrical conditions in a molecular beam the image is a truncated triangle with very steep sides and essentially flat on top. There is a rounding of the corners and the edges of the mark fall off asymptotically. A fairly good approximation to the geometrical shape can be had by drawing lines through the two sides and the half width a can be computed by taking the average of the displacements at the top and bottom of the area of the zero mark included between the two lines. This

value was used. The error introduced by this procedure is in this case relatively slight. Thus the first three criteria for the use of this equation are justified as inspection of the microphotometer curves in Fig. 4 will show.

FIG. 4.



As the long hours of making a measurement gradually closed up the image slit S_2, the half width of the beam suffered a gradual decrease. In order to correct for this decrease in

beam width, a study was made of the influence of the value of the half width a on the deposit. The effect of the value of a on I/I_0 can be seen at once by expanding the exponentials in the expression for I/I_0 in series and neglecting higher powers of $(a/S)^2$ than the first. This gives.

$$\frac{I}{I_0} = 4\left(\frac{S\alpha^4}{S^5}\right)\left(1 - \frac{S\alpha^2}{S^2} + \frac{\frac{S\alpha^4}{S^4}}{2!} \pm \ldots\right)a.$$

Thus for a given ratio of $S\alpha/S$ and S, I/I_0 varies directly with a, and I/I_0 will have quite different values at a given value of $S\alpha/S$ for different values of a. The effect of the change in shape of the curve computed for Bi at 875° C. at 120.7 R.P.S. for $a = 0.11$ mm. and for $a = 0.08$ mm. is shown in Fig. 3. The dashed curve applies to $a = 0.08$ and it is seen that the effect is slight. Since, however, I/I_0 is approximately proportional to a it is legitimate in computing the theoretical curves to use an average value of a. This was determined by measuring a' on the zero mark of the initial deposit (clean slit) and measuring the width of slit S_2 before and after the run (S'_2). The average value of a was then taken as $a = a'[(S_2 + S_2')/2S_2]$ and was so used in computation.

DETERMINATION OF THE VAPOR PRESSURE.

In order to calculate the heat of dissociation of Bi_2 one must evaluate the equilibrium constant K_p. In order to get K_p one must determine the partial pressures, p_1 due to atoms of Bi and p_2 due to molecules of Bi_2.

The relation used by Knudsen [8] for determining the vapor pressure, p_1 in mm. of Hg, of a uniform atomic gas from the mass of gas, g_1 in grams, evaporating per second through an opening of area a in cm.^{2} when the atomic mass is m, at a temperature T is

$$g_1 = p_1 a \sqrt{\frac{m}{2\pi RT}}$$

when R is the gas constant per mole. This applies to a hole in an infinitely thin diaphragm and the width of the slit. For

a uniform diatomic gas such as Bi_2 the vapor pressure is given by

$$g_2 = p_2 a \sqrt{\frac{2m}{2\pi RT}}$$

where g_2 and p_2 correspond to the mass and pressure of Bi_2 and the value of m for Bi_2 is $2m$ or twice the value of m for Bi. Thus in a molecular beam composed of Bi and Bi_2 in equilibrium in a crucible at partial pressures p_1 and p_2 respectively, the total mass in grams of Bi evaporated in one second is

$$g = g_1 + g_2 = a \sqrt{\frac{m}{2\pi RT}} (p_1 + \sqrt{2}\, p_2).$$

The quantity $p_1 + \sqrt{2}\, p_2 = P'$ can thus be evaluated from the weighings of the crucible during the run. The vapor pressure in the crucible is, however, $P = p_1 + p_2$. In order to calculate P from the data obtained in weighing it is necessary that beside P' a ratio between p_1 and p_2 be known.

Consider N_0 molecules of Bi_2 gas originally undissociated in the crucible. Let α be the degree of dissociation of Bi_2 in the crucible at a temperature T, after equilibrium is reached. Then $(1 - \alpha)$ will be the fraction of undissociated Bi_2. Since the reaction is of the type $Bi_2 \rightarrow 2Bi$ the vapor at equilibrium will contain the following numbers of the two species of particles:

$$N_0 (1 - \alpha) \text{ molecules of } Bi_2$$

and

$$2N_0\alpha \text{ atoms of Bi.}$$

The total number of particles N is thus $N = N_0 (1 + \alpha)$. The mole fractions are then

$$X_{Bi} = \frac{2N_0\alpha}{N_0(1 + \alpha)} = \frac{2\alpha}{1 + \alpha},$$

$$X_{Bi_2} = \frac{N_0(1 - \alpha)}{N_0(1 + \alpha)} = \frac{1 - \alpha}{1 + \alpha},$$

so that the partial pressures p_1 and p_2 are

$$p_1 = X_{Bi} P = \frac{2\alpha}{1+\alpha} P,$$

$$p_2 = X_{Bi_2} P = \frac{1-\alpha}{1+\alpha} P$$

where P is $P = p_1 + p_2$.

The ratio between P and the quantity P' evaluated by weighing is thus $P/P' = (p_1 + p_2)/(p_1 + \sqrt{2}\, p_2)$. Inserting the values of p_1 and p_2 above, one obtains P as

$$P = \frac{(1+\alpha)\, P'}{\sqrt{2} + \alpha\,(2-\sqrt{2})}.$$

The value of α which is required above and is also used in the evaluation of the heat of dissociation must be inferred from the analysis of the velocity spectrum. It will later be shown how it is possible from the ratio I/I_0 in the velocity spectrum as a function of the displacement S to evaluate the relative amounts of Bi atoms and Bi_2 molecules in the beam. This ratio is not the same as the ratio of the partial pressures in the beam. To calculate the relation between α and the relative densities of the two species *in the beam* one must recall that the velocity v of the Bi atoms relative to the velocity V of the Bi_2 molecules is given by $v = \sqrt{2}\, V$. Hence the beam is richer in Bi than is the crucible since the higher velocity favors the escape of Bi in the ratio $v/V = \sqrt{2}$. Let x be the fraction of Bi atoms in the beam and $1 - x$ that of Bi_2 molecules. Since in the oven the ratio of the two species is

$$\frac{N_{Bi}}{N_{Bi_2}} = \frac{2N_0\alpha}{N_0(1-\alpha)} = \frac{2\alpha}{1-\alpha}$$

The ratio of Bi and Bi_2 in the beam is

$$\frac{N'_{Bi}}{N'_{Bi_2}} = \frac{2\sqrt{2}N_0\alpha}{N_0(1-\alpha)} = \frac{2\sqrt{2}\alpha}{1-\alpha}$$

while the total number of particles in the beam

$$N' = 2\sqrt{2}N_0\alpha + N_0(1-\alpha)$$
$$= N_0(1 + 1.828\alpha).$$

Then x becomes

$$x = \frac{2\sqrt{2}\,\alpha}{1 + 1.828\alpha} \quad \text{and} \quad 1 - x = \frac{1 - \alpha}{1 + 1.828\alpha};$$

therefore

$$\alpha = \frac{x}{2.828 - 1.828x} \quad \text{and} \quad 1 - \alpha = \frac{2.828\,(1 - x)}{2.828 - 1.828x}.$$

Using the relations between p_1, p_2, P and P', one obtains, for the dissociation constant K_p defined as $K_p = p_1^2/p_2$, the value

$$K_p = \frac{4\alpha^2 P'}{(1 - \alpha)(\sqrt{2} + 0.586\alpha)}.$$

Placing the values of P' from the weighing and of α in terms of x obtained by an interpretation of the analysis of the deposit into the expression above, one can determine K_p. It is important to note that the quantity x is not given by the relative contribution of the Bi atoms and Bi_2 molecules to the thickness of the deposit. It represents the *relative number of Bi atoms in the beam.* In the *deposit* each Bi_2 molecule contributes two atoms while the Bi atoms contribute but one atom. Hence the analysis of an *observed deposit* of Bi and Bi_2 gives relative amounts of Bi and Bi_2 which must be converted into terms of x.

From K_p the heat of dissociation may then be computed from the values of K_{p_1} and K_{p_2} evaluated for the temperatures T_1 and T_2 by the Van't Hoff equation,

$$Q = 2.303\,R\left(\frac{T_1 T_2}{T_2 - T_1}\right)\log_{10}\frac{K_{p_2}}{K_{p_1}}.$$

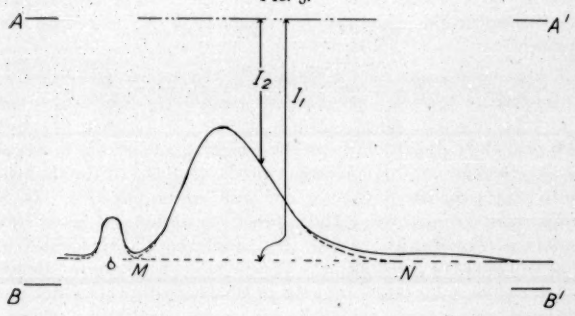
In the present determination T_1 and T_2 were the temperatures in the slit chamber T_s at two temperatures of measurement. Actually Q was obtained from the slope of the straight line curve of $\log_{10} K_p$ plotted against $1/T_s$ drawn by least square reduction through the experimental points.

REDUCTION OF OBSERVATIONS AND CALCULATION OF RESULTS.

a. Measurement of Microphotometer Records.

By means of fiducial marks already mentioned, the microphotometer curves for the initial deposit with zero mark were superposed on those for the final run. Three typical contact prints of the superposed curves are shown in Fig. 4, the fiducial marks being out of the picture in order to conserve space. The enlargement is just twice the original deposit. In Fig. 5 the diagrammatic sketch of such a record is given. The

FIG. 5.



fiducial marks B and B' represent no absorption and thus maximum intensity. A and A' represent total absorption. O represents the center of the slit system and hence the center of the zero mark. This is the zero of abscissæ and in all the curves shown the displacement S will be plotted as cm. of displacement from this point. In all but the contact prints the curves shown have been reduced to the actual displacement in cm. by division by 2. In two of the six runs computed, the distribution fell definitely to the level of the initial deposit at the points M and N. In other cases it did not do so. The other curves showed a final deposit lying above the initial deposit at M and N of about constant amount. This was probably caused by diffusely reflected molecules due to a heightened gas pressure as the chamber warmed up towards the end of a run. Possibly some of these molecules also

emanated from the slit S_2 as it was choking up. The effect was somewhat reduced by the use of the fourth slit which was inserted in five of the runs for this purpose.

By means of a travelling microscope, the distances I_1 and I_2 of the spectrum and corresponding initial deposit from the zero transmission line AA' were measured at intervals of 1 mm. at the ends and $\frac{1}{2}$ mm. near the peak. The ratio I_1/I_2 represents the ratio of the *intensities of the light transmitted* through the initial deposit and the velocity spectrum. This ratio of light intensities for the purposes of the analysis was translated into the relative densities of deposit by the use of Beer's law. By measuring the relative intensities of timed deposits of a constant molecular beam on the microphotometer records, it was found that the intensities of these deposits were governed by the law

$$I_1 = I_0 e^{-\beta t_1} \text{ and } I_2 = I_0 e^{-\beta t_2}$$

where I_1 and I_2 correspond to two intensities corresponding to two times (and hence densities of deposit), t_1 and t_2. In this case β is the absorption coefficient, which was found to be constant. Thus

$$\frac{I_1}{I_2} = e^{\beta(t_2 - t_1)} \text{ and } \log \frac{I_1}{I_2} = \beta(t_2 - t_1).$$

Hence $t_2 - t_1$ represents the thickness of the deposit and log I_1/I_2 is $(t_2 - t_1)\,\beta$. As the relative values of $t_2 - t_1$ at different points were all that was required, the absorption coefficient β was merely a scale factor and was not used. Hence curves of log I_1/I_2 as ordinates were plotted against values of the actual displacement S in cm. as abscissæ. Such curves are shown as the crosses in Figs. 6 and 7, 6 being taken at a temperature of 827° C. and 7 at a temperature of 875° C., the optimum temperature.

b. Analysis of the Experimental Curves.

Since the displacement S_α of the most probable velocity α for an atom or a molecule of known molecular weight in a molecular beam from an oven at a temperature T_s can be computed from the constants of the apparatus and the speed

FIG. 6.

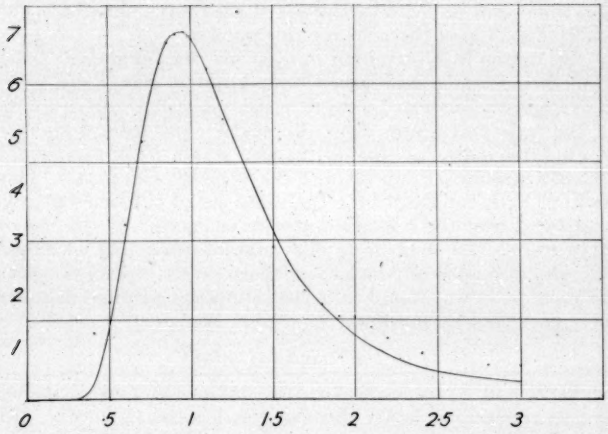

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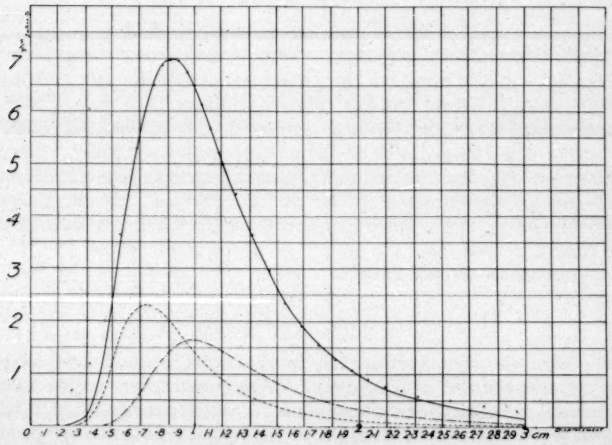
FIG. 7.


7
6
5
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0 1 2 3 4 5 6 7 8 9 1 11 12 13 14 15 16 17 18 19 2 21 22 23 24 25 26 27 28 29 3 cm

of rotation, this value was computed for both Bi atoms and Bi_2 molecules for the conditions of each of the six runs calculated up. With a knowledge of the half slit width a the ratio I/I_0 was computed in terms of the displacement S for each of the curves from

$$\frac{I}{I_0} = e^{-(S\alpha/(S+a))^2}\left[\left(\frac{S\alpha}{S+a}\right)^2 + 1\right] - e^{-(S\alpha/(S-a))^2}\left[\left(\frac{S\alpha}{S-a}\right)^2 + 1\right]$$

for the case of Bi and Bi_2. As found by Zartman, neither the curve for Bi nor that for Bi_2 coincided with the observed curves. It was clear that the observed curves were composed of Bi and Bi_2 molecules in definite relative proportions. These were determined by trial and error, account being taken of the fact that each Bi_2 molecule condensed contributes twice as much to the density of the curve as does a Bi atom. Thus for x atoms of Bi and $1 - x$ molecules of Bi_2 in the beam, curves for the deposit were plotted for x atoms of Bi and $2(1 - x)$ atoms from Bi_2 using the experimental data. These curves were then added graphically and the scale of the ordinate of the peak of the curve adjusted so as to coincide with the ordinate of the peak of the observed curve. The results of three such trials for the curve at 875° C. with $x = .61$, $x = 0.60$ and $x = 0.59$, respectively, are shown in Fig. 8 as circles, crosses and triangles. On a larger scale it is found that the coincidence between $S = 0.5$ and $S = 1.4$ (i.e. about the peak) is very satisfactory for $x = 0.60$ but is to the right of the $x = 0.61$ and to the left of the $x = 0.59$ curves. It is thus possible to determine the value of x in the beam to 1 per cent. of composition with considerable certainty. The deviations of the observed curves from the observations at large and small ordinates do not affect the fit and will therefore be discussed later. In this fashion the full curves of Figs. 6 and 7 were drawn, and the values of x and $1 - x$ were determined in all six runs between 827° C. and 947° C. The results of these analyses are given in Table I. In this table the first column gives the average half-width a of the undeflected beam in cm., column two, T_c, the crucible temperature governing the vapor pressure, column three, T_s, the temperature of the crucible slit governing the dissociation, column four, the revolutions per second, column five,

the time of the run in hours, and column six, the values of x and $1 - x$ inferred.

FIG. 8.

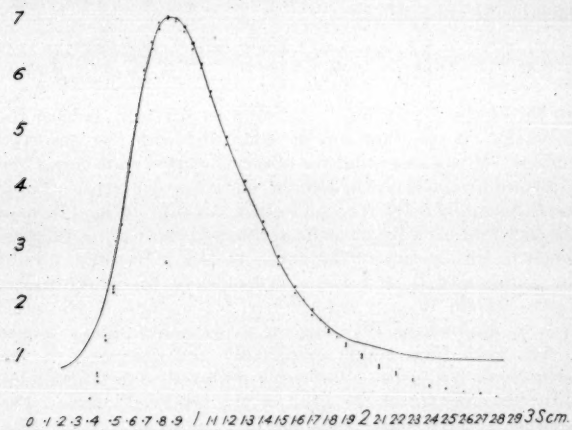


TABLE I.

a in cm.	T_c ° C.	T_s ° C.	n.	t hrs.	I/I_0.	
					x.	$1 - x$.
.06	827	827	120.7	21	.55	.45
.01	827	851	120.7	18	.45	.55
.08	851	875	120.7	13	.40	.60
.1	875	899	120.7	12	.36	.64
.072	899	922	120.7	8	.33	.67
.1	922	947	120.7	5	.31	.69

VAPOR PRESSURE DETERMINATIONS.

The summarized vapor pressures for Bi appear in the "International Critical Tables" [9] to be given by the relation $\log_{10} P = -52.23\,(200/T) + 8.87$, which applies to a range from 1210° to 1420° absolute only. The present investigation covers a range from 1100° to 1220° absolute. Inasmuch as

it was possible to determine the vapor pressures directly for each run by merely weighing the crucible, it was considered best to utilize the data at hand. The results of these measurements and data pertaining thereto are contained in Table II and are self-explanatory. A plot of the $\log_{10} P'$ against $1/T_c$

TABLE II.

Crucible temp. abs.	T_c	1088	1100	1124	1148	1172	1195
Slit opening cm.²	a	.005	.0095	.009	.008	.005	.009
Ratio of depth and width of slit	L/b	.7	1	.25	1.3	4	1.1
Correction factor	f	.7503	.6848	.8710	.6321	.3999	.666
Pressure outside of slit mm. Hg		1×10^{-5}	3×10^{-5}	1×10^{-5}	1×10^{-5}	1×10^{-5}	1×10^{-5}
Evaporation rate gm. per hr.	g	.061	.201	.208	.2147	.155	.742
P' calculated mm. Hg		.134	.2324	.2553	.301	.349	.9375
P' corrected by multiplying $1/f$	P'	.1786	.3394	.2931	.4762	.8727	1.408
$\log_{10} P'$		−.74813	−.46932	−.53297	−.32222	−.05912	.14850
$1/T_c\times10^{-3}$		.9191	.9090	.8896	.8710	.8532	.8368
From curve I (Fig. 11) by least square reduction	$\log P'$	−.733	−.625	−.422	−.222	−.031	1.402
P' used for calculating K_p	P'	.1849	.2372	.3785	.5998	.9312	1.381

is shown in curve I of Fig. 9, the straight line being a least square reduction and the crosses being the observed points. The values of P' taken from the least square reduction curve were used in the calculation of the heat of dissociation. The values of P' were then used with the degree of dissociation α to give P the true vapor pressure. The least square reduction of the values of P obtained plotted against $1/T$ give the equation for the vapor pressure of Bi in this range as $\log_{10} P = -52.23 \times 195.26/T + 8.56$. This line lies below but close to the line drawn from the data in the "International Critical Tables." The values observed are given in Table III.

FIG. 9.

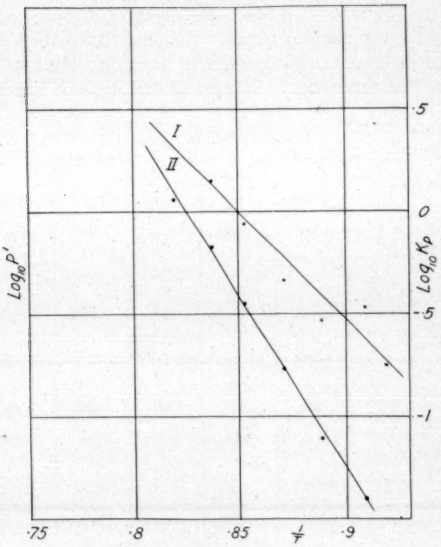


TABLE III.

Observed Values of the Vapor Pressure of Bi in mm. Hg at Temperatures T in Degrees Absolute.

P.	T.
0.2689	1100
0.2125	1124
0.3966	1148
0.7417	1172
1.203	1195
1.584	1220

CALCULATION OF HEAT OF DISSOCIATION.

As stated elsewhere, the heat of dissociation is obtained from the relation

$$Q = 2.303\, R \left(\frac{T_1 T_2}{T_2 - T_1} \right) \log_{10} \frac{K_{p_2}}{K_{p_1}}$$

where T_1 and T_2 are the absolute slit chamber temperatures corresponding to the values of α for which K_{p_1} and K_{p_2} were calculated. Actually the values of K_p for different values of T_s were calculated from the data and plotted as $\log_{10} K_p$ against the values of $1/T_s$ as shown in curve II, Fig. 9. The points are the values of $\log_{10} K_p$ actually computed, while the straight line is a least square reduction. The data used in this calculation are given in Table IV which is self-

TABLE IV.

T_c Abs.	P' mm.	T_s Abs.	x.	$1-x$.	α.	K_p.	$\log_{10}K_p$.	$1/T_s$.
1100	.2372	1100	.45	.55	.2244	.03988	−1.39924	$.909\times10^{-3}$
1100	.2372	1124	.55	.45	.3018	.07780	−1.10902	$.8896\times10^{-3}$
1124	.3785	1148	.60	.40	.3466	.1721	− .76422	$.871\times10^{-3}$
1148	.5998	1172	.64	.36	.386	.355	− .44977	$.8532\times10^{-3}$
1172	.9312	1195	.67	.33	.4179	.6739	− .1714	$.8368\times10^{-3}$
1195	1.381	1220	.69	.31	.4404	1.1465	.05937	$.8197\times10^{-3}$

explanatory. The slope of the line gives at once the *best* value of the heat of dissociation per mole, divided by 2.303 R. The least square reduction value obtained from these data is 77,100 ± 1200 calories per mole.

It is to be noticed that the points lie fairly well on a straight line, showing no consistent indication of curvature. This gives considerable confidence in the accuracy of the method and in the value of the heat deduced.

Objection might be raised to the use of two temperatures T_c and T_s, differing by 24° C. in these measurements. These were necessary to prevent choking of the slit, although at 827° the run was made with $T_c = T_s$ without choking. The rate of evaporation from the large Bi surface in the crucible and the large area of the throat of the slit chamber compared to the area of the source slit S_1 allowed of pressure equilibrium at T_c. At the same time, the rate of egress through S_1 was so slow that most of the molecules and atoms in the vapor had several impacts with the walls of the slit chamber at T_s before escaping. It seems therefore logical that the vapor pressure was governed by T_c while α was governed by T_s. In any case the error introduced was probably slight, as calculation showed that with the accommodation coefficient

for Bi on steel on a smooth surface the escaping molecules left at a temperature 8° C. above T_c after a *single* impact, and the surface of the steel was not smooth.

DISCUSSION AND CONCLUSION.

The previous determinations of the heat of dissociation by Leu cannot in their original form be compared with these results. Fraser, pointing out certain errors made by Leu, attempts to correct Leu's values by recalculation. He cites the value as 26,500 ± 11,600 calories per mole. Unfortunately, in his calculation Fraser uses denary logarithms without converting them to exponential logarithms, for which the formula is derived. His value should therefore be multiplied by the factor 2.303. This gives the Leu-Fraser value as 61,100 ± 26,700, which is in reasonable agreement with the value found above. The curve between K_p, plotted against $1/T$ from Fraser's calculation of Leu's data, yields points that depart widely from a straight line, dropping continuously and quite rapidly at lower temperatures. This drop accounts for the large limits of error. In the present work the points lie nicely on a line within the limits of experimental uncertainty.

In a recent note in the *Bulletin* [10] *of the American Physical Society* Almy and Sparks evaluate the heat of dissociation of Bi_2 from band spectra and obtain the value of 41,500 calories per mole. This value is much lower than that of either Leu or the writer. Owing to the brief character of the published abstract, it is impossible to find the cause of the difference. It is felt, however, that the value obtained by the writer must certainly be correct in order of magnitude.

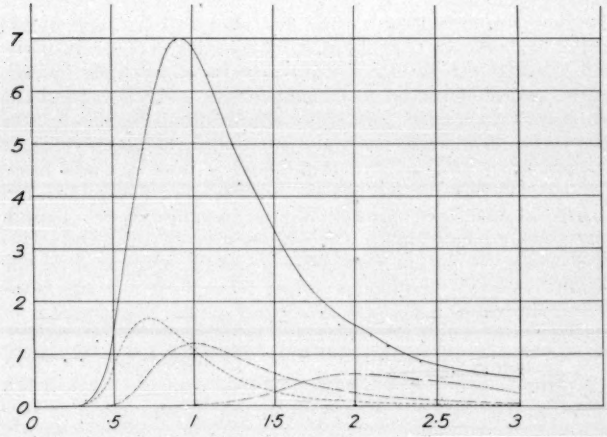
It was hoped that despite the fact that the molecular beam consisted of two molecular species, a test of the distribution law might be found by comparing the curve obtained from the addition of the curves for Bi and Bi_2. In this direction the results were not as gratifying as hoped for. The nature of the deviations can be seen by comparing the curves of Figs. 6 and 7 with the experimental points. These deviations appear in general in the four other curves computed. The first deviation is that below abscissæ 0.5 cm. both experimental curves are higher than the computed curves. The same in general is true of the points at abscissæ greater than 2.5 cm. Part of

this deviation around M and N, Fig. 5, is doubtless due to what were assumed to be diffuse molecules. It was to improve the zero mark and overcome this difficulty that the fourth slit was introduced. The condition was slightly improved in this fashion, but other difficulties appear to have been introduced. It is probable that the condition due to diffuse molecules can better be remedied by some radical changes in the housing, permitting of more complete and rapid evacuation.

Between ordinates 1.3 cm. and about 2 cm. there was in every case, except that of Fig. 7, a deficiency of observed molecules relative to theory. Many possible causes were investigated and none served to account for the difficulty except the observation that the only curve obtained which did not show the phenomenon was the one made under the best conditions *without the fourth slit* S_4. The belief is that the light brass carriage of this slit warped on heating over long hours and displaced itself unsymmetrically across the beam. This in effect would have made the values of a in the expressions $S + a$ and $S - a$ unequal and would have accounted for the result. Certain conditions at the base of the carriage after a run indicated a definite possibility of the displacement of this slit. Finally a deviation is to be noted in Fig. 6 at ordinate 2 which is not fortuitous. It is the appearance of a slight but definite peak. This peak is indicated on all curves except those at the highest temperatures, 922° C. and 947° C. It is displaced towards lower abscissæ as the temperature increases and it reduces in height with increasing temperature. These criteria place it as a peak, or spectrum, due to a new and very heavy species of Bi molecule. The location of the peak fixes it as being the molecule Bi_8. This presumption is borne out in Fig. 10, which is the experimental curve of Fig. 6 at 827° C. compared with a curve consisting of 44 per cent. Bi, 54 per cent. Bi_2 and 2 per cent. Bi_8 in the beam, instead of the 45 per cent. Bi and 55 per cent. Bi_2 assumed for Fig. 6. It is seen that the peak ascribed to Bi_8 is adequately taken care of on this assumption. It is therefore probable that there is present at the lowest temperature somewhat less than 2 per cent. of a new molecular species, Bi_8. The presence of Bi_8 in small amounts may in part account for the deviation of the

observed and theoretical curves at abscissæ greater than 2, although diffuse molecules must also have been present as shown on the high velocity side. That a heavier molecule should be present is not surprising. That it is Bi_8 and not Bi_4 or Bi_6 seems rather strange, as either of these forms would seem more likely. It is further obvious that Bi_3, Bi_4 and Bi_6

FIG. 10.



are definitely absent, which is again surprising since the heavier molecule appears.

In conclusion the writer wishes to acknowledge his thanks to the late Professor E. E. Hall who originally designed the velocity analyzer and under whose direction this work was begun. It is also desired to thank Dr. I. F. Zartman for his advice in the initial phases of this work, as well as Mr. F. F. Coleman, in collaboration with whom this work was initially carried on for two months. The writer's thanks are due to Mr. George Kraus, without whose patient mechanical assistance the problem would have been impossible, as well as to Dr. Edwin McMillan, and Dr. I. Estermann whose sugges-

tions at times have been an invaluable aid. The writer especially desires to express his gratitude to Professor Leonard B. Loeb, under whose direction and with whose kind instruction from the beginning to the end the work was brought to its successful conclusion. Finally the writer desires to express his thanks to the Rockefeller Foundation for the Fellowship which for a period of two years enabled him to devote his full time to this problem.

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To Members of the Institute.—The seventh Exhibition of Chemical Plants and Apparatus will be held at Cologne, Germany, May 18–27, 1934. As in former years an "Achema" Annual will be published which will give particulars concerning the present state and development of chemical plants and apparatus. It also will contain preparatory information with regard to the coming "Achema" exhibition as well as detailed information on what visitors may see therein. The last "Achema" Annual for the years 1928–30 contained 370 pages. This valuable annual report will be supplied gratis to members of the Institute upon payment of postage (2 International prepaid postal forms). The address: Dechoma, Achema-Geschäftsstelle, Seelze bei Hannover, Germany.

C.

No Ethyl Gasoline for Sweden.—(*I. & E. Chem.*, News Edition, Sept. 20, 1933.) In response to a Swedish oil importing company's application for permission to import and sell Ethyl gasoline, a group of experts appointed by the State Institute of Technology have declared that: "Even though the use of tetraethyl lead as an antiknock is connected with some risk of poisoning, acceptance of the company's application would have been recommended if there had been in the country a definite need for this antiknocking agent. However, there is no such need, since we possess in our own motor alcohol an excellent and harmless antiknocking substance that so far has not been fully utilized."

C.

Quick-Frozen Ducks.—(U. S. Dept. of Agriculture.) Ducks, chickens and other poultry preserved by quick freezing and held in cold storage six months or more are scarcely to be distinguished from fresh killed birds in both appearance and taste. By the quick freezing system birds can be frozen in about two hours as contrasted with 36 to 48 hours by slow freezing. In the experiments, Long Island ducks and other poultry were frozen by the use of a fog or mist of brine at four degrees below zero. The birds were then rinsed with clear water and dipped in ice water which formed a thin film or glaze of ice protecting the carcasses from dessication or freezer burn during the period of cold storage. The quick frozen ducks were found to be distinctly superior to the slow frozen ducks from the standpoint of bacterial content of the flesh and acidity of the fat. Eating tests proved the quick-frozen ducks distinctly superior in aroma, flavor and juiciness.

C.

THE DETERMINATION OF THE DIRECTION AND VELOCITY OF FLOW OF FLUIDS.

BY

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Under conditions of steady flow, with low turbulence and negligible pulsation, and where the direction of flow is known, the velocity of flow of a fluid at a point can be ascertained by the use of a Pitot tube directed into the stream. If the flow is in a long duct or pipe, an impact tube and a piezometer ring may be substituted. Both of these methods can be made to give results that are accurate within one per cent. If the flow has considerable pulsation, all methods fail and it is necessary to reduce the pulsations before accurate measurements can be made.[1]

The accuracy of the Pitot tube results in large part from the fact that it is very insensitive to misalignment. The tubes which are standardized in America, Fig. 1 (see the A.S.H. & V.E. Standard Code for Testing Fans) and in Germany, Fig. 2 (the Prandtl tube[2]) indicate constant velocity head up to an angular displacement of about 17 degrees on either side of the true direction of flow.

The other great advantage of these tubes is that they have a coefficient of unity and, in that respect, are not sensitive to minor variations in form and dimensions, so that they can be used confidently without preliminary calibration.

If the flow is two-dimensional, that is, each element is moving in a plane, but the direction of flow in that plane is not known, it is still possible to use the Pitot tube for finding both

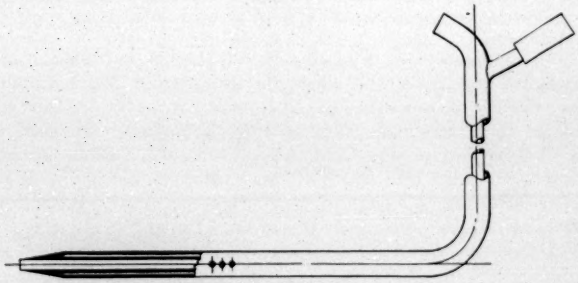
[1] H. F. Hagen, "Pulsation of Air Flow from Fans and Its Effect on Test Procedure," A. S. M. E., Dec. 1932.

[2] Kumbruch, "Messung strömender Luft mittels Staugeräten." Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, Heft 240.

Winkel, "Stauröhren zur Messung des Druckes und der Geschwindigkeit im fliessenden Wasser." *Z. V. d. I.*, June 9, 1923.

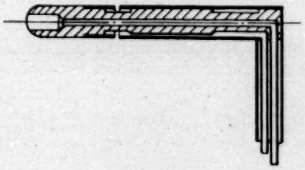
direction and velocity. The percentage change in velocity head indicated by a Prandtl tube as it is displaced angularly in the flow plane, from the upstream direction, is shown in Fig. 3.[3] It will be seen that for a large angular displacement the percentage change is considerable. To use the Pitot tube for finding direction, the tube can be directed approximately into

FIG. 1.



Standard Pitot Tube.

FIG. 2.

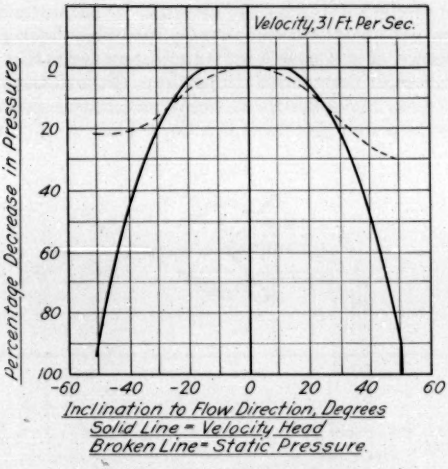


Prandtl tube.

the stream by observing the direction giving maximum velocity head. The tube is then rotated about 40 degrees in the plane of flow (position *a*, Fig. 4) and the velocity head and angular position are read. The tube is again rotated to a position on the opposite side of the flow direction until the same manometer reading is obtained and the angle is noted

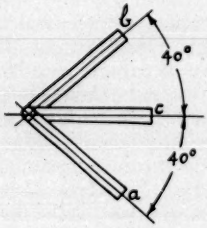
[3] From Kumbruch, *loc. cit.*

FIG. 3.



Variation of reading of Prandtl tube with inclination.

FIG. 4.

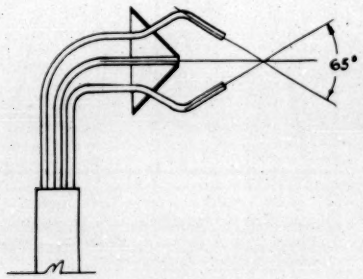


(position *b*, Fig. 4). If the angle between positions *a* and *b* is bisected (position *c*, Fig. 4) the direction of flow is obtained with considerable accuracy. For many uses this procedure may be satisfactory but it will yield accurate results only when the flow field is uniform through the range from *a* to *b*. If the

Pitot tube is offset so that the impact opening is in line with the stem of the tube this difficulty will be elimintaed.

An improvement on this arrangement has been employed in the design of a yawmeter.[4] In this design (Fig. 5) three impact tubes of very small dimensions (hypodermic needles) are employed, the outer tubes being inclined at exactly equal angles to the axis of the central tube. The two inclined tubes

FIG. 5.



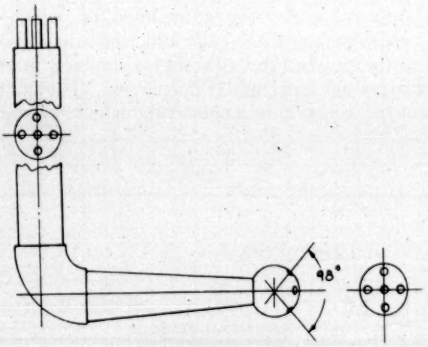
Yawmeter.

are connected to the ends of a differential manometer. When the instrument is rotated in the flow plane, until the differential manometer reads zero, the central tube will be directed into the stream. This instrument has been used to observe pressure and direction at a point and this demands that the end of the central impact tube should be the center of rotation during the orientation of the instrument. To accomplish this, the three tubes are mounted on a member which moves over a quadrant with the axis of rotation passing through the end of the central impact tube. For three-dimensional flow another pair of impact tubes, similar to the two inclined tubes, is attached in a plane at right angles to the first pair and is connected to another differential manometer. The instrument now has five tubes and three manometers. After the first pair of tubes is put in balance, the second pair is similarly

[4] Reports and Memoranda Nos. 156, 445 and 844, (British) Advisory Committee for Aeronautics.

balanced by moving the first quadrant around a second quadrant which is mounted at right angles to the first quadrant. This instrument is reported to be of very great sensitivity to direction and has been used in the investigation of airfoil models in wind tunnels. It is a research device and not adapted to general investigations such as air flow in ducts.

FIG. 6.



Taylor tube.

A variant on this is the Taylor tube,[5] Fig. 6, in which the tube terminates in a spherical head with five holes, of which the central one is located at the tip and the others are in two planes at right angles to one another and are all at 49 degrees with the central hole. Each hole communicates with a separate tube inside the main tube. The test results on this tube [6] indicate that it is not as sensitive as the yawmeter just described. It is used by inclining the tube first in the plane of one pair of holes and then in the plane at right angles, in each case until the connected differential manometer reads zero. There are five tubes and three manometers. The coefficient of the impact tube is unity.

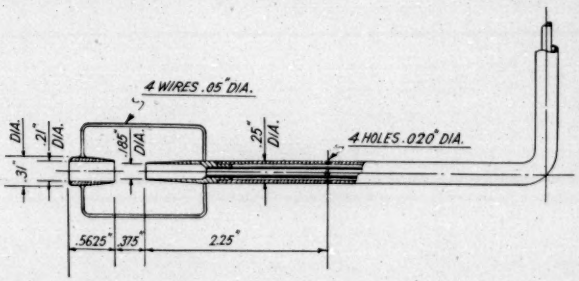
This paper concerns itself primarily with two-dimensional

[5] Winkel, *loc. cit.*
[6] Winkel, *loc. cit.*

flow and does not consider spiralling or other three-dimensional modes of flow. For such flow, various modifications of the Pitot tube can be used to find direction of flow with much greater sensitivity than is obtainable with the standard forms of Pitot tube. Examples are to be found in the paper by Winkel [7] but these suffer the disadvantage of having coefficients which are considerably different from unity and would demand calibration in every case.

The author has devised a modification which is easily applied to a standard Pitot tube and which has the same coefficient as the simple Pitot tube and is similarly insensitive to slight changes in form and dimensions. The modification consists of the addition of a short tube which is located ahead

FIG. 7.



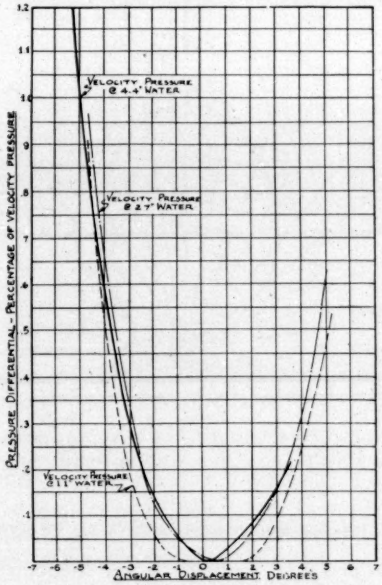
Marks modification of the Pitot tube.

of the Pitot tube by means of stiff wires. The short tube is preferably stream-lined on its exterior and the optimum proportions are approximately as shown in Fig. 7. As the bore of the short tube is greater than that of the Pitot tube, the flow at the Pitot tube is unchanged when it is correctly oriented. When the Pitot tube is inclined to the air stream, the flow is disturbed by the short tube and the impact reading of the Pitot tube is lowered. The curves of Fig. 8 show the sensitiveness of this device. If the manometer can be read to .001 in., the sensitiveness of this device is 2.7 deg. for a velocity

[7] *Loc. cit.*

head of 1.1 in., 1.1 deg. for 2.7 in., and 0.6 deg. for 4.4 in. velocity head. The static pressure readings are unaffected and consequently this modification acts as a direction finder and does not interfere with the normal use of the Pitot tube.

FIG. 8.

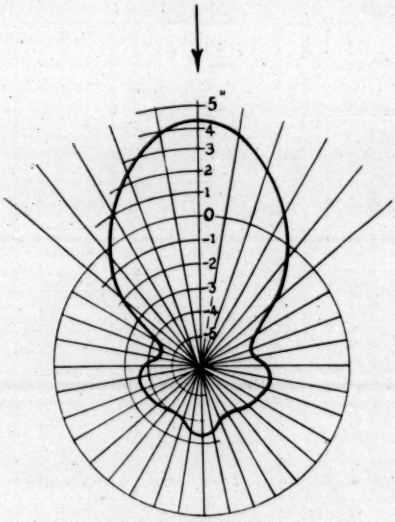

VELOCITY PRESSURE @ 4.4" WATER
VELOCITY PRESSURE @ 2.7" WATER
VELOCITY PRESSURE @ 1.1" WATER
PRESSURE DIFFERENTIAL - PERCENTAGE OF VELOCITY PRESSURE
ANGULAR DISPLACEMENT DEGREES

Variation of reading of Marks tube with inclination.

An entirely different method of finding the direction of two-dimensional flow and a more sensitive one is possible whenever it is permissible to insert a small tube normal to the plane of flow. Numerous researches in aerodynamic laboratories have shown the general characteristics of the variation of pressure around such a tube as indicated by a manometer

connected to a small hole in the tube. The polar diagram, Fig. 9, shows results obtained in the author's laboratory with a tube 1/8 in. in outside diameter and with a hole 0.025 in. diameter. Radii outside the full circle are pressures in excess

FIG. 9.

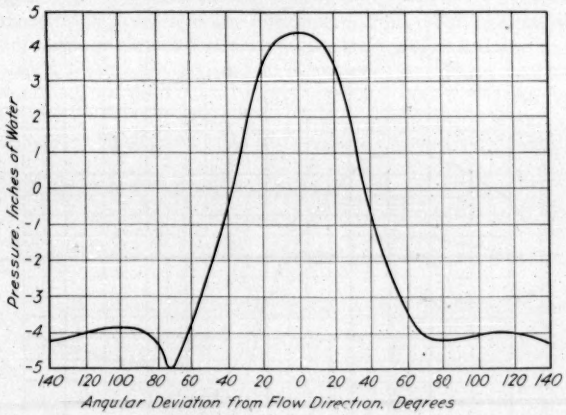


Polar diagram of pressure distribution on transverse tube.

of the static pressure; radii inside are vacuums. The same results are shown with rectangular coördinates in Fig. 10. When the hole is directed into the flow, the true impact pressure is recorded. As the tube is rotated from this direction, the recorded pressure diminishes and becomes equal to the static pressure at an inclination of about 35 degrees; from there on it becomes negative. It will be seen from Fig. 10 that the rate of change of indicated pressure with the angle of rotation is a maximum at the angle of about 35 degrees, at which the impact pressure is equal to the static pressure. Ad-

vantage has been taken of this fact to devise an instrument of great sensitivity to direction. The tube is provided with three holes, of which two are about 70 degrees apart and the third exactly bisects the angle between the other two. The

FIG. 10.



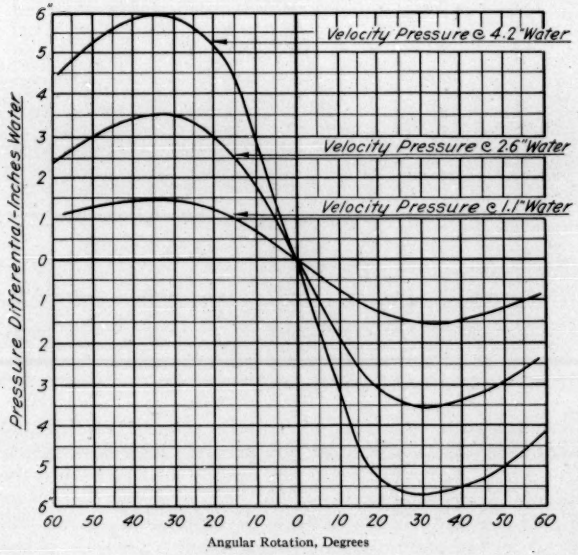
Pressure registered at hole in transverse tube.

outer holes are connected to opposite ends of a differential manometer and the central hole to a separate manometer. The central hole will be pointing exactly upstream when the differential manometer reads zero. Fig. 11 shows that for an impact pressure of 4.2 in. of water the differential pressure will be 0.3 in. per degree of rotation, or about 7 per cent. of the velocity head per degree. This same percentage is found to hold approximately constant for the same tube with other velocity heads. Investigations with a 3/8 in. tube with holes 0.025 in. diameter, and with the outer holes 60 degrees apart, show consistently a change in reading of the differential manometer of about 7 per cent. of the velocity head per degree of rotation of the tube. This rate of change of the reading obviously applies only for a moderate angular rotation.

The author's tests were made in an air stream discharging

from a well-rounded 6-in. nozzle into the atmosphere and with the tube located about one-half of the nozzle diameter from the nozzle. The nozzle was preceded by about 30 feet of duct 38 in. in diameter and the air was supplied by a fan which has very slight pulsation. Under these conditions the flow of air

FIG. 11.


Velocity Pressure @ 4.2" Water
Velocity Pressure @ 2.6" Water
Velocity Pressure @ 1.1" Water
Pressure Differential-Inches Water
6" 5 4 3 2 1 0 1 2 3 4 5 6"
60 50 40 30 20 10 0 10 20 30 40 50 60
Angular Rotation, Degrees

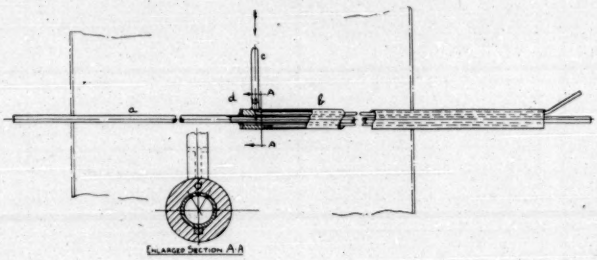
Differential pressure on angular rotation of transverse tube.

from the nozzle is presumably very uniform. The central hole gave steady readings. The differential manometer connected to the side hole was not steady but fluctuated through a range of about 5 per cent. of the velocity head. This instability at the side holes reduces the effective sensitiveness of the instrument but still makes it possible to locate the direction of flow with an accuracy closer than 1 degree. The manometer reading for the central hole, when directed into the stream, is

found to be exactly the same as that of a Pitot tube similarly directed; the coefficient of the central hole is consequently unity.

In order to find the velocity of flow, it is necessary to know the static pressure as well as the impact pressure. As stated previously, the static pressure exists at a location on the tube about 35 degrees from the direction of flow. Unfortunately, this angle varies with the value of the Reynolds number and also with the ratio of length to diameter of the tube. Experimental determinations of this angle have been tabulated by Dryden and Hill [8] and show values varying from about 31 degrees to 38 degrees. As the pressure changes very rapidly

FIG. 12.



Transverse tube with static tube.

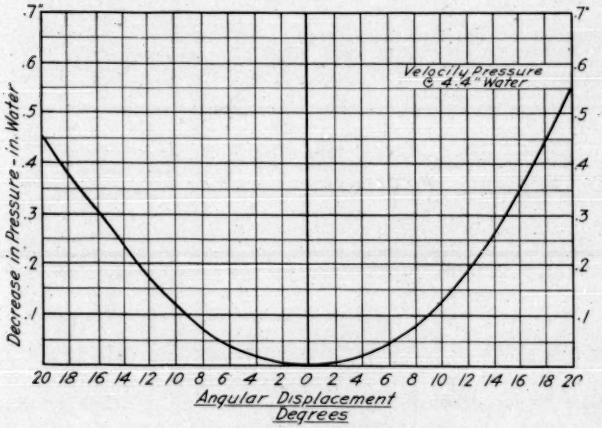
in this range, it is obvious that a transverse tube is not a satisfactory device for determining static pressures and that it must be supplemented by a piezometer ring or other device. If a static pressure traverse is desired, the transverse tube *a*, Fig. 12, may be made slidable in an outer tube *b* which is provided with a static tube *c* with standard static holes *d*. If the transverse tube is provided with a key exactly opposite to the central hole and the outer tube is slotted exactly opposite to its static tube, the static tube will always point in the same direction as the central hole. After an impact reading has been taken, the outer tube can be slid along the transverse tube

[8] Dryden and Hill, "Wind Pressure on Circular Cylinders and Chimneys." Research Paper No. 221, Bureau of Standards, 1930. Table 4, p. 672.

until the static tube covers the central hole and static pressure can be read on a separate manometer. The static pressure will not be read exactly at the same location as the impact pressure but neither is this the case with the usual Pitot tube.

In cases where the flow is not two-dimensional or the plane of flow is not known accurately, so that there is no certainty that the transverse tube is normal to the plane of flow, there may be a component of flow parallel to the axis of the transverse tube or an angle of yaw. The effect on the impact

FIG. 13.



Effect of angle of yaw on transverse tube reading.

tube reading of the angle of yaw is shown in Fig. 13, and is seen to produce an error of about one per cent. for 6 degrees and about 4.5 per cent. for 12 degrees of yaw.

The author has used the transverse tube for the determination of the direction and velocity of flow of air leaving a bend in a rectangular duct and for investigating the conditions of flow in a straight duct. The observations obtained are consistent and apparently accurate.

BIOCHEMICAL STUDIES OF SOY BEAN MILK AND CHICKEN PROTEIN.

BY

JOSEPH SAMUEL HEPBURN, A.M., M.S., Ph.D.,
KEUM SUNG SOHN, B.S., M.D.,
and
LAURENCE PATRICK DEVLIN.

SOY BEAN MILK.

Legumes play an important part in the diet of the oriental races. In Korea, soy beans are used extensively as a foodstuff. They serve as the basis of two foods, Doo Pu and soy bean milk. In a previous paper[1] we have described the preparation of Doo Pu, which is known as Do Fu in Chinese, and reported the results of its analysis. This paper is devoted to a study of soy bean milk.

The Korean people passed immediately from a primitive condition to the status of an agricultural community without the intervention of a pastoral age. For this reason, soy bean milk was the only milk used by the Koreans as an accessory food until the introduction of cows in comparatively recent times. Even at the present time, soy bean milk is much used as a food and beverage especially during the summer months.

The soy bean milk was prepared according to the Korean method by Dr. Sohn who is a native of that country. Dry soy beans were soaked with twice their volume of water for 24 hours. Heat was then applied until the water was almost at its boiling point. The beans were thoroughly ground with the water in a mortar; the resulting mass was poured into a coarse linen bag; and the liquid portion was obtained by squeezing. The white filtrate was soy bean milk. Samples were prepared as required, and were stored in a mechanically refrigerated ice box at an average temperature of 8.0° C., or 46.5° F.

A sample of the soy bean milk was analyzed, using the

[1] Hepburn and Sohn, *American Journal of Pharmacy*, 1930, CII, 570.

methods of the Association of Official Agricultural Chemists,[2] and found to have the following percentage composition:

Total Solids	6.92
Fat-free Solids	4.57
Moisture	93.08
Crude Fat	2.35
Crude Fiber	0.00
Crude Protein	3.50
Ash	0.46
Nitrogen free Extractives	0.61
Calcium	0.034
Phosphorus (P_2O_5)	0.091

Therefore, 100 grams of this sample of soy bean milk yielded 38.7 calories, including 21.9 calories derived from fat, 14.3 calories derived from protein, and 2.5 calories derived from carbohydrate (nitrogen-free extractives). The 100 calorie portion weighed 258.4 grams.

Soy bean milk and cow milk may be compared with respect to their chemical composition. According to Sherman,[3] in cow milk, fat-free solids range between 8.5 and 9.5 per cent., fat between 3 and 6 per cent., protein between 3.0 and 4.0 per cent., ash between 0.70 and 0.78 per cent., and carbohydrate between 4.6 and 5.0 per cent., while its total phosphorus, expressed as phosphoric anhydride, is approximately 0.23 per cent., and its calcium 0.120 per cent. Therefore, with the single exception of protein, each of these constituents was present in the soy bean milk to a lesser extent than in cow milk.

The rate of spontaneous formation of acid in soy bean milk and in cow milk was determined. In each of two experiments, a bottle of freshly prepared soy bean milk and a bottle of fresh, grade AA cow milk were kept side by side in the ice box. At intervals of 24 hours, the contents of each bottle were thoroughly mixed by agitation; an aliquot portion of each was removed, and diluted with cold, recently boiled, distilled water; and its acidity was determined by titration with 0.1 normal sodium hydroxide solution, using phenolphthalein as an indicator. The acidity was expressed as the number of cc. of decinormal alkaline hydroxide required to neutralize the

[2] "Official and Tentative Methods of Analysis of the Association of Official Agricultural Chemists," Third Edition, 1930.

[3] Sherman, "Food Products," Second Edition, New York, 1929, 67, 83, 84.

acids present in 100 cc. of milk. The results are presented in Table I. In the same experiment, on the same day, the cow

TABLE I.
Influence of Time of Storage at 8° C. on Acidity.

Time in Days.	Experiment A.		Experiment B.	
	Soy Bean Milk.	Cow Milk.	Soy Bean Milk.	Cow Milk.
0	7.7	12.1	16.5	13.2
1	9.9	13.2	17.6	18.7
2	11.0	14.3	23.1	27.5
3	20.9	16.5	41.8	51.7
4	26.4	52.8	44.0	72.6
5	31.9	71.5	62.7	90.2

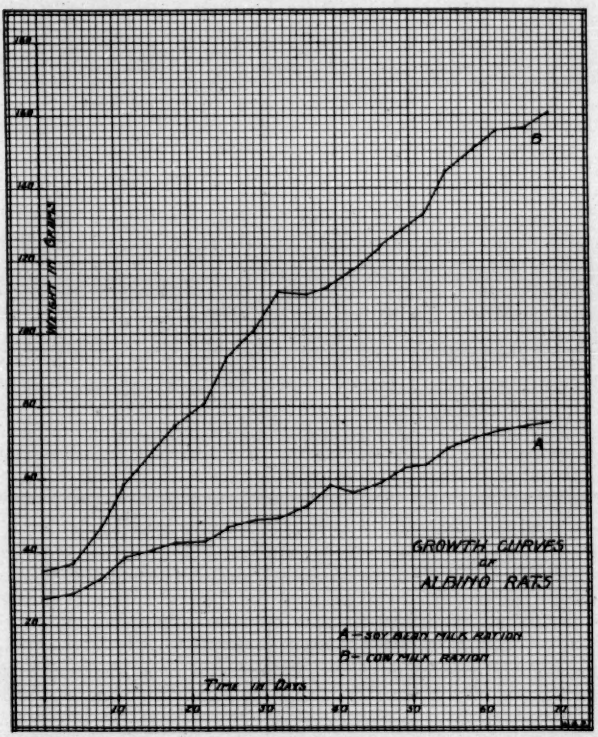
milk usually had a higher acidity than the soy bean milk. This difference in behavior was most marked during the last two days of storage. All the samples had coagulated on the fifth day; therefore, the soy bean milk curdled spontaneously at a lower acidity than the cow milk.

Young albino rats were used in a feeding experiment which extended over a period of 69 days; 4 rats were used in the experiment proper on soy bean milk, and 4 rats in the control experiment on cow milk. The constituents of each ration were weighed and mixed daily at the same hour immediately before feeding. The rations had the following percentage composition: In the experiment proper, corn meal 15, whole wheat flour 15, soy bean milk 70; in the control experiment, corn meal 15, whole wheat flour 15, cow milk (grade AA) 70.

The mass of ration fed was always in excess of that ingested, and was increased as the animals grew and required more food. Each day, the weight of each ration fed and the weight of its uneaten portion were determined; the difference beween these weights represented the actual daily ingestion. The animals were given an ample supply of fresh clean water.

Each rat was weighed twice a week prior to feeding. The average growth curve for the rats of each group is given in Fig. 1. The average initial weight of the rats in the experiment proper (27.7 grams) was somewhat less than that of the control rats (34.9 grams). At the end of the feeding period of 69 days, the average weight of a rat in the experiment proper

FIG. 1.



was 75.9 grams, an average gain of 48.2 grams or 174.0 per cent. of the average initial weight; the average weight of a control rat had increased to 160.4 grams, an average gain of 125.5 grams or 359.6 per cent. of the average initial weight. Although the controls had a slightly greater initial body weight, yet their percentage gain in average weight was over twice that shown by the rats on the soy bean milk ration. The

per cent. of their respective initial weights gained by the individual rats ranged from 98.2 to 225.0 in the experiment proper, and from 301.0 to 385.1 in the control experiment.

During the entire period of 69 days, the rats in the experiment proper ate 4997.3 grams of ration and gained 192.8 grams in body weight, while those in the control experiment ate 7000.4 grams of ration and gained 501.9 grams in body weight. Therefore, 25.9 grams of the soy bean milk (experiment proper) ration or 13.9 grams of the cow milk (control) ration were required to produce a gain of 1 gram in body weight.

None of the rats developed any avitaminosis.

CHICKEN PROTEIN.

The purpose of this study has been to determine the relative nutrient value of chicken protein and casein. The chicken protein had been prepared according to the procedure of Osborne and Heyl.[4] The connective tissue (including adipose tissue) was removed from the muscles as completely as possible. The lean meat was passed through a chopper; and the constituents, which were soluble in water, 95 per cent. alcohol, absolute alcohol, and ether, were removed by successive digestions with those solvents at room temperature. The dry protein, thus prepared, was ground to a fine powder in a drug mill. The casein was of the grade designated "highest purity."

In the feeding experiments, young albino rats were used. Two such experiments were made, a preliminary and a final.

Preliminary Experiment.—In this experiment, the constituents of the ration and their respective amounts by weight were: Protein (chicken protein *or* casein) 18, sucrose 15, starch 29.5, powdered agar 5, salt mixture 2.5, hydrogenated vegetable oil 20, butter fat 10, cod liver oil 4.3, dried ale yeast 10. The salt mixture gave an adequate supply of the inorganic ions: calcium, magnesium, sodium, potassium, iron, phosphate, sulphate, and chloride. All the requisite vitamins were furnished by the yeast, butter fat, and cod liver oil. The dried ale yeast contained 38.89 per cent. protein. This

[4] Osborne and Heyl, *American Journal of Physiology*, 1908, XXII, 433-439.

ration, with casein as the protein, had been used by one of us[5] in a study of by-product yeast. In the preparation of each ration, the various ingredients other than fats and oils were thoroughly mixed in a large mortar. The hydrogenated vegetable oil, which was semisolid, and the butter fat were melted; and the cod liver oil was added to the resulting liquid, which was then poured upon the mixture of the other ingredients in the mortar and thoroughly incorporated by trituration. The resulting mass was solid at room temperature. It was kept in a mechanically refrigerated ice box, and fed, in adequate quantity, to the rats daily. The actual daily consumption was determined by weighing the amount fed and the amount remaining uneaten. Five rats were fed the chicken protein ration, and 4 rats the casein ration. They were given an adequate supply of fresh, clean water. This experiment extended over a period of 72 days. Each rat was weighed daily at the same hour, prior to feeding.

On the chicken protein ration, the average initial weight was 43.3 grams; the average gain in weight in 72 days was 255.4 per cent. of the average initial weight; and the gains shown by individual rats ranged between 228.1 and 319.3 per cent. of their respective initial weights. These rats consumed 3.78 grams of ration for each gram of gain in weight.

On the casein ration, the average initial weight was 48.9 grams; the average gain in weight in 72 days was 246.2 per cent. of the average initial weight; and the gains shown by individual rats ranged between 210.0 and 302.2 per cent. of their respective initial weights. These rats consumed 3.81 grams of ration for each gram of gain in live weight.

In this experiment, the chicken protein ration apparently was slightly superior to the casein ration, since the former had produced a slightly greater gain in weight with the consumption of slightly less ration per unit of gain in weight. However, every 114.3 grams of ration contained 3.89 grams of yeast protein in addition to 18 grams of either chicken protein or casein, i.e., the yeast protein was 17.77 per cent. of the total protein. Therefore, it was decided to repeat the experiment with the ration modified by a decrease in its yeast content so

[5] Hepburn, JOURNAL OF THE FRANKLIN INSTITUTE, 1925, CC, 767–770.

regulated that, while yeast protein formed a lower per cent. of the total protein, sufficient yeast was still present to satisfy adequately the vitamin B (F and G) requirements of the experimental animals.

Final Experiment.—Accordingly, in this experiment, each ration was modified so that the yeast content of the formula was reduced to 7.5 grams. Each 111.8 grams of ration now contained 2.92 grams of yeast protein in addition to 18 grams of either chicken protein or casein; and the yeast protein formed 13.96 per cent. of the total protein. The dried ale yeast content of the ration (6.71 per cent. by weight) was found adequate to prevent the development of avitaminoses due to lack of vitamin B, and was somewhat above the amount of dried brewers' yeast (6 per cent.) generally used for this purpose.[6]

The animals were young male albino rats, and were litter mates. The chicken protein ration was fed to 5 rats, the casein ration to 4 rats. The experiment extended over a period of 57 days. The average growth curve for the rats of each group is given in Fig. 2.

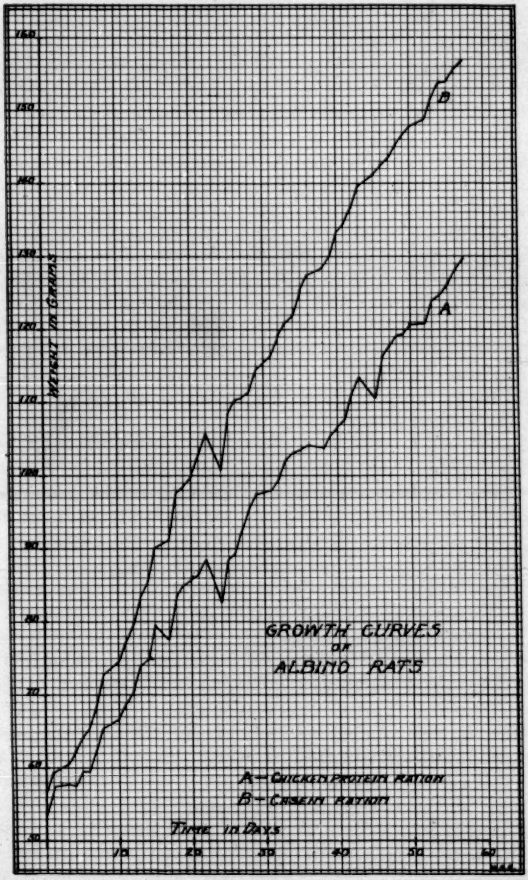
On the chicken protein ration, the average initial weight was 53.8 grams; the average gain in weight in 57 days was 141.3 per cent. of the average initial weight; the gains shown by individual rats ranged between 128.1 and 151.0 per cent. of their respective initial weights. These rats consumed 4.37 grams of ration for each gram of gain in weight.

On the casein ration, the average initial weight was 56.8 grams; the average gain in weight in 57 days was 176.2 per cent. of the average initial weight; the gains shown by individual rats ranged between 160.3 and 197.0 per cent. of their respective initial weights. These rats consumed 3.97 grams of ration for each gram of gain in weight.

Since the two rations differed only in respect to the protein (chicken protein or casein), this experiment demonstrated chicken protein to be inferior to casein; for the casein ration uniformly produced greater gains in weight with the consumption of less ration per each unit of gain in weight.

[6] Munch, "Bioassays: A Handbook of Quantitative Pharmacology," Baltimore, 1931, 831.

FIG. 2.


WEIGHT IN GRAMS
GROWTH CURVES OF ALBINO RATS
A = CHICKEN PROTEIN RATION
B = CASEIN RATION
TIME IN DAYS
B
A

Chicken protein therefore was a less efficient protein than casein.

These studies have been supported, in part, by a grant from the Constantine Hering Fund.

SUMMARY.

Soy bean milk, prepared in the Korean manner, had approximately the same protein content as cow milk. The other nutrient compounds were present in soy bean milk to a lesser extent than in cow milk.

Soy bean milk curdled spontaneously at a lower acidity than cow milk. However, the same period of time was required for spontaneous curdling.

In the feeding experiments, the ration containing soy bean milk produced gain in weight less rapidly than the ration containing cow milk, and with less efficiency, i.e., with the consumption of more ration per unit of gain in weight.

In feeding experiments, chicken protein was found to be a less efficient protein than casein.

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Hahnemann Medical College and Hospital of Philadelphia.

The Infinitesimal in Nature.—A copy of the Research University Record, Vol. 14, No. 3, recently has come to our notice. In it, PROFESSOR DRAPER describes: "How Inconsistent Use of Definition Defeats Science and Mathematics." Since a paradox represents the materialization of an inconsistency, this article contains many examples of mathematical paradoxes. Mathematicians and those who employ mathematics as a diversion should be interested in such freaks of faulty reasoning. The author points out the weaknesses or faults present in such proofs that: (1) There are no numbers greater than two; (2) There can be a continuous function without a derivative; (3) Three equals one; (4) Infinity squared is zero. C.

Weather Peculiarities (U. S. Dept. of Agric. Clip Sheet, No. 791).—Analysis of a set of long-time records for Iowa and adjacent states leads the Weather Bureau to announce that: "Abnormal weather tends to create more abnormal weather." Thus an unusually hot June is more likely than not to be followed by an unusually hot July and a colder than ordinary January by a February with an average temperature below normal.

Observe that this data was gathered chiefly in the Middle Western States. Many persons hold the opinion that the weather of the Eastern Seaboard States is much more independent in nature. C.

Bodies of Wood and Steel.—At present some sort of argument appears to exist between two large automobile companies as to whether car bodies constructed wholly of steel are superior to those which are a combination of steel and wood. The company advocating a combination claims that hardwood in the body reinforces the steel, absorbs shocks and eliminates the rattle and rumble.

The most interesting feature of the contest is a description of the experiments to ascertain the comparative strength of all-steel and steel-wood bodies. The two types of bodies were subjected to a weight of 9000 pounds applied diagonally through the bodies. The all-steel body was wrenched 11 inches out of line, the roof was destroyed, the doors were jammed and every steel body pillar buckled. It was wrecked beyond repair. The wood-steel body was deflected only 4 inches. All the doors were intact and in working order. No glass was broken, except for a crack in the corner of the windshield. When the load was lifted the body returned to within one inch of its normal position, and was completely repaired within twenty-four hours. C.

THE MICHELSON-MORLEY EXPERIMENT.

BY

A. A. MERRILL.

In recent times there has probably been no experiment made, the understanding of which has caused so much trouble as the Michelson-Morley experiment. One of the explanations of this experiment, made by a noted physicist, states that it means "Time is relative." I contend that this explanation only makes things more confused than they were before.

My own explanation is a very simple one and is based upon two phenomena which have been known for years and which have been checked time and time again long before Einstein was born. As I see it, the M–M experiment can be explained satisfactorily without considering Einstein's system at all.

The first phenomenon is taken from the athletic world. In running races it is well known that the greatest interest is created if the runners arrive at the finish line simultaneously. Now if, of two runners (*a*) and (*b*), (*b*) runs more slowly than (*a*), then, if we handicap (*a*) we may make the race more interesting. This handicap can be made by allowing (*b*) to run a shorter distance than (*a*) but starting them simultaneously. If we give the proper handicap, then both (*a*) and (*b*) may reach the finish line simultaneously and the race will be interesting.

The second experiment is the well known fact that it is very easy to slow up the *motion* of light by making it pass through some dense but transparent medium. This is Huyghens' explanation of what we call the "Index of refraction." I said *motion* not velocity. Velocity is the ratio of two *motions* and involves the use of come local clock.

We must remember that from the point of view of light, and having regard to the electronic theory of matter, all solid bodies are like a galaxy of stars, which of course have open spaces so far as light is concerned. Remember also that

gravitation varies as the mass and inversely as the square of the distance. From this I claim that we should expect that the local force field within glass, say, will be much more intense than it will be in air for instance. It is just this change in local force fields within different media, all of which are transparent, which accounts for the slowing up of the *motion* of light passing through these media. Direct measurements by Foucault, Fizeau and Michelson show that light travels with different *motions* in different media. Let us combine all of these well known facts and apply the resultant to the M–M experiment.

All force fields must be considered as vectors. The force vector which determines the *motion* of the earth through space, shortens *all* lengths (including scales) parallel to itself and so this effect is hidden on its own system. The mathematical measure of this shortening is the famous Lorentz-Fitzgerald contraction namely $\sqrt{1-\beta^2}$ where $\beta = v/C$. But this force vector also slows up the *motion* of light in its own direction. You see the velocity may not be slowed up because that depends upon where you place your clock. If the *motion* of your clock is varied as the *motion* of light is varied then the velocity will *not* vary. Just this is how Einstein makes C an invariant *as a velocity, not as a motion.*

Nature evidently wanted to make the race interesting and so, while she knew it would be harder for light to run parallel to her major vector than in a direction at right angles to that vector, she fixed things up by shortening the length of the track parallel to that vector. Her handicap was so accurately calculated that the race has been practically a dead heat for years, although we expected it to be a walk-over.

She certainly made the race interesting. We have been repeating the experiment and betting on it for a generation, but we do not yet agree as to why it ends as it ends. My explanation of this race is that the slower runner runs a shorter distance and so it is a dead heat within the limits of small experimental errors. We do not have to bring in, as an explanation, any such ambiguous, confusing statement as "Time is relative" nor do we have to consult Einstein in order to understand the Michelson-Morley experiment.

Surely any physicist who gives "Time is relative" as an explanation of the M-M experiment is blind to an error in his reasoning, because whenever we compare different *motions* (light in this case) we imply the existence of at least two simultaneities, one later than the other. But this certainly means that there is *one definite absolute time interval between the two simultaneities.*

Tagging Fish.—(White Metal News Letter, Sept. 1933.) It may not be difficult to tag a fish but Dr. Rounsefell in charge of the Alaska Herring Investigation for the U. S. Bureau of Fisheries has had his difficulties in the past when he tried to recover the tags. The fish are tagged for the purpose of tracing their migration which is done by recording the points at which the fish and their tags are caught. Since the herring and the tags are quite small, ordinary methods of tag recovery prove rather tedious.

Accordingly, Dr. Rounsefell has developed a magnetic nickel tag and has installed a system of electro-magnets for recovering the tags. The great majority of the herring in Alaska are put through reduction plants for the manufacture of fish oil and fish meal. A powerful electro-manget was installed at the discharge end of each of the meal dryers and as the dry meal emerges from these cylinder dryers, it falls over the magnet, which catches the tags.

C.

Soldering Aluminum Successfully.—(*I. & E. Chem.*, News Edition, Sept. 20, 1933.) H. A. G. Gunnelius and G. Kraft of the Technologic Institute of Stockholm, Sweden, have developed a procedure for soldering aluminum with tin and other solders. The chief difficulty encountered when soldering aluminum is to obtain a surface absolutely free from oxides. Since commercial aluminum and most of its alloys contain more or less silicon, the surfaces to be soldered are cleaned with hydrofluoric acid or with solutions developing that acid. The acid must be carefully removed by washing with water and the water then removed by dipping the metal into alcohol, preferably methanol. Any solder may be used and if the corrosion resistance of the connection is not very important an alloy of 85 per cent. tin and 15 per cent. aluminum is satisfactory. Where corrosive conditions are encountered a higher melting-point solder should be used—for instance, 90 per cent. aluminum, 9 per cent. copper and 1 per cent. silver.

Calgon.—The Mellon Institute of Industrial Research announces the induction of a fellowship providing for research upon molecularly dehydrated phosphates of alkali metals. Calgon, a member of this group, is essentially sodium metaphosphate. This product is found to be of utility in cleaning various constructional materials, including stone, brick and terra-cotta. It also is satisfactory for cleaning shrubbery and trees begrimed with smoke and soot. Calgon also appears to have some solvent effect upon residual calcium soaps.

C.

ON THE HYPOTHESIS OF A CRITICAL FIELD IN SUPERCONDUCTIVITY.

BY

DAVID RITTENHOUSE INGLIS,

Ohio State University.

The possible existence of a critical strength of the magnetic field for superconductivity assumes of late an added interest as a test of the validity of the many proposed theories of the phenomenon. Experimental tests of this hypothesis of Silsbee [1] were reported in this journal by Tuyn and Kamerlingh Onnes.[2] Among the experimental results that deal with the simple dependence of the existence of superconductivity upon temperature, current density and field strength (rather than with the variation of the residual resistance with these quantities), those which were considered to support the Silsbee hypothesis measure the total critical current in a wire as a function of the radius. (The results on the critical current through a hollow cylinder in the case when the current is not, compared with the case when it is, conducted back along the axis of the cylinder may be equally well explained on the hypothesis of critical field or of critical current density.) The accuracy of the experiments is such that the results are fairly convincing, but not entirely certain. Others of the measurements are here interpreted in such a way as to indicate the existence of a critical field, rather than critical current density.

If it is the field strength that has a critical value, the current must flow on the outside surface of the superconducting part of a piece of metal.[3] (The field induced by the current at the surface is then directly proportional to the surface current density, and the hypothesis of a critical current density on the surface is identical in its consequences with that

[1] F. B. Silsbee, *Journal Washington Acad. Sci.*, **6**, 597 (1916); *Sci. Pap. Bur. Stand.*, **14**, no. 307 (1917).

[2] W. Tuyn and H. Kamerlingh Onnes, JOURNAL FRANKLIN INST., **201**, 379 (1926); Leiden Comm. 174a.

[3] M. von Laue, *Phys. Zs.*, **21**, 793 (1932).

of a critical field strength at the surface.) With the hypothesis of a critical volume current density, the current, as it grows, may penetrate the superconductor, saturating successively deeper layers to a current density just above the critical value, so that they are no longer superconducting (during the growth of the current) and the field may change in them. In this case the critical strength of applied magnetic field (parallel to the wire, for example) is that which just induces a circular current to the critical density in the entire wire, and this is just sufficient to annul the external field at the axis. This gives a critical parallel field proportional to the radius of the wire, whereas the experimental values[2] are practically independent of the radius, in support of the Silsbee hypothesis.

Assuming a critical field strength, and using Maxwell's equations for the vicinity of a perfect conductor, von Laue[3] deduced the ratio of the critical strength of the field applied parallel to the wire to that of the field applied perpendicular to the wire as 2. It is of interest to note that this success is no support of the hypothesis there used, since the hypothesis of a critical volume density leads to the ratio $\pi/2$, in quite as good agreement with the experimental value 1.6. But even without this sanction, the interpretation of the measurements in terms of the tangential field induced by the currents and the failure of the interpretation in terms of the currents induced by applied fields leave practically no doubt of the validity of assuming a microscopic critical field strength.

NOTES FROM THE U. S. BUREAU OF STANDARDS.*

SPALLING OF MARBLE ON WASHINGTON MONUMENT.

In connection with some proposed repair work on the Washington Monument, this Bureau is coöperating with National Parks, Buildings, and Reservations in a study of marble masonry joint treatments. The point in question is to determine a method of preventing the spalling which occurs on the marble facing. This spalling has been going on for several years and has reached such a stage as to mar the appearance of the lower portion of the obelisk. It occurs mainly on the lower 150 feet of the structure and affects the marble mainly along the horizontal mortar joints. A possible explanation is that the marble is supporting more than its share of the superimposed weight, and that this results in the spalling. With uniform distribution of the load over a horizontal section of the masonry at the ground level and maximum wind pressure, no part would be stressed as much as 700 lbs./in.^{2}. Tests recently made on blocks of the same material which had been exposed to the weather for about 70 years indicated a bearing power of more than 5,000 lbs./in.^{2}. Hence the spalling and cracking of the marble indicate that it is actually stressed much more than the theoretical 700 lbs./in.^{2}.

Details of the early construction of the monument are not available, but it is believed that a rubble masonry filling exists between the outside marble ashlar and inside walls of granite ashlar. Thin mortar joints in the ashlar masonry and thicker mortar joints in the rubble fill would account for uneven distribution of the loading.

The experiments now in progress are for the purpose of determining if a proposed plan of widening the horizontal marble joints for an inch or more from the surface and refilling with a more elastic mortar will overcome the spalling. For this purpose it was considered desirable to use marble of

* Communicated by the Director.

the same kind as that in the monument and which had been exposed to the weather for a similar period of time. Some blocks were taken from the top of the old Patent Office Building for the experiments, since the marble in it came nearest to satisfying these conditions.

SOLARIZATION OF GLASS.

During the past month the Bureau's radiometry section took occasion to summarize the results of an investigation which has been in progress for the past three years on the photochemical changes in glass as recognized by changes in the ultraviolet spectral transmission when exposed to wide bands of filtered ultraviolet solar radiation, and also when exposed to isolated wave-lengths of homogeneous radiation from the quartz mercury arc. The results to date are as follows:

It is impracticable to use filtered ultraviolet radiation from the quartz mercury arc in accelerating the stabilization ("aging") of the transmission of ultraviolet window glasses. Just as great accuracy is obtained by stabilizing the glass under unfiltered quartz lamp radiation.

Ultraviolet radiation of short wave-lengths (254 to 300 millimicrons) has the greatest effect in reducing the transmission of window glasses. The greatest "antagonistic" action in rejuvenating the ultraviolet transmission of solarized glasses is produced by wave-lengths in the region of 365 millimicrons.

For each wave-length, there is an equilibrium level of photochemical action (as recognized by the ultraviolet transparency) depending upon the previous exposure of the glass.

The shorter the wave-length (between 254 and 365 millimicrons) of the homogeneous exciting radiation, the lower the equilibrium value of the transmission. If the ultraviolet transmission is below the equilibrium value, as the result of previous exposure to wave-lengths shorter than the one under consideration, the exposure to this wave-length *increases* the transmission to the equilibrium value. Similarly, if by heat treatment or exposure to wave-lengths longer than the one under consideration, the transmission is raised above the

equilibrium value for this wave-length, then exposure to this wave-length *decreases* the transmission to the equilibrium value. To what extent this change in equilibrium level in transmission is owing to more than one photochemical change in the glass, is a problem requiring further investigation.

DIRECT CURRENT AMPLIFIER FOR RADIOMETERS.

Since the invention of the electron tube, some eighteen years ago, numerous arrangements of electric circuits have been described for amplifying small electric currents; for example, from thermopiles and photoelectric cells. But few of these proposals have survived; and none have come into general use for making precise radiometric measurements. This is owing to the instability of the electronic circuit used and to the lack of provision for electrically standardizing the amplifier—a necessary procedure since there are no reliable sources of ultraviolet for standardizing the combined radiometer and amplifier.

Recently, considerable time has been devoted by the Bureau's radiometry section to assembling various combinations of screen-grid electron tubes and resistances to give the desired amplification, and testing their reproducibility from day to day. The materials employed (microammeter, screen grid amplifier tubes, resistances, dry batteries, and photoelectric cells) are readily obtainable in commerce. The assembly is compact in form and easily transported—weight about twenty-seven pounds.

During the past month the performance of the device has been studied intensively both in the field and in the laboratory.

It was found that, after a preliminary operation for five to ten minutes to attain temperature equilibrium in the amplifier tubes, there is no fluctuation in the zero scale reading of the microammeter either (*a*) when testing the amplification sensitivity of the instrument, or (*b*) when making measurements of ultraviolet intensities, of the sun and of artificial sources.

The indicator response scale reading was found to be linear within the accuracy of the microammeter used. Owing to the selective wave-length response of the photoelectric cell,

this device like all selective radiometers, must be calibrated in absolute value by means of the standard balanced thermopile (differential actinometer) and filter radiometer.

FOREIGN INTEREST IN BUREAU'S RADIO AIDS TO AIR NAVIGATION.

The developments of the Bureau of Standards for enabling airplane pilots to fly and land blind are coming into use in several foreign countries. Recent notices indicate that these include England, France, Germany, and Switzerland. The Canadian government several years ago installed airway radiobeacons of the visual indicating type developed by the Bureau.

One of the most striking of these foreign adaptations of the American work is an installation at Tempelhof Field, Berlin, of the high-frequency radio beam for blind landing. The Deutsche Versuchsanstalt für Luftfahrt some months ago set up an experimental beam transmitter to test its efficiency. The results were so promising that a method and instrument were devised for controlling the shape of the landing path; a line of constant received intensity is not followed, but one in which the intensity is below normal at the start of the glide, changing to above normal at a point near the end of the glide. A service installation was put into operation at Tempelhof in September, 1933, and four airplanes were equipped to make use of it.

At Zürich-Dübendorf, Switzerland, a similar blind landing system was installed and was expected to be put into operation in January, 1934.

Engineers from a number of other countries, including Holland, Japan, and the Union of Socialist Soviet Republics, have visited the Bureau of Standards laboratories and the installation at the Newark, N. J. Airport to make a study of the system.

In England there has been installed at the Croydon Airport a radiobeacon of the visual type similar to that developed by the Bureau. The Marconi's Wireless Telegraph Company has developed a modified form of the reed indicator for this system. Instead of rotating the reed unit as a whole in its shock mounting, the face only is rotated; this requires an ec-

centric window and extended white tab on the 65-cycle reed. It is understood that the beacon is ready for regular operation, working in conjunction with another visual-type beacon at Paris, (Le Bourget Airport), France.

In France two of the visual-type beacons are in use, the one at Paris and another at Lyon. The same modulation frequencies, 65 and 86 2/3 cycles, are used at all the beacons. The French beacons differ from the original American design in that the modulation frequencies are introduced by rotary condensers in the antenna circuits. Reed indicators identical with those originally developed by the Bureau are used. The French installations were made by the Societe d'Entreprises Electro-Techniques. Publications describing the system state that it has proved very successful and is in daily use.

A GLASS ELECTRODE POTENTIOMETER SYSTEM FOR THE DETERMINATION OF THE pH VALUES OF WEAKLY BUFFERED SOLUTIONS.

In the electrometric measurement of the pH values of buffered solutions, more dilute than M/10,000, by means of quinhydrone and hydrogen electrodes, the resistance of the solution, escape of carbon dioxide, acid properties of the quinhydrone, and polarization of the electrodes are so disturbing that the emf readings may vary as much as 5 to 30 m.v. or 0.1 to 0.5 pH unit. The isohydric indicator technique is apparently applicable within 0.1 pH to such solutions, and distilled water, but has not heretofore been compared with a reliable emf method. By adding Varley shunts to a modification of the vacuum tube potentiometer used by Partridge, keeping the grid attached to the circuit, and using a Thompson glass electrode, emf readings can be made within 0.1 to 2.0 m.v. on weakly buffered solutions and distilled water, and the pH values agree with those obtained by the isohydric indicator method. This apparatus is also suitable for measuring the pH of solutions containing active or reducing agents, such as chlorine or tannins, where the hydrogen and quinhydrone electrodes and indicator methods might fail. For a complete description, Research Paper no. 634 in the January number of the *Bureau of Standards Journal of Research* should be consulted.

ANALYSIS OF WOOL-COTTON TEXTILES.

As a result of recent standardization activities, there has arisen a need for a more accurate method for the determination of wool in mixtures of wool and cotton. For example, the Trade Practice Ruling adopted on May 26, 1930 by the Federal Trade Commission requires that "the word 'wool' shall not be used in any way in the labeling, advertising, merchandising or selling of knit underwear unless the percentage by weight of wool contained in the garment is stated." The Commercial Standard for "Wool and part-wool blankets" established by the joint action of producers, distributors, and users, effective April 1, 1933, provides for the labeling of part-wool blankets with the guaranteed minimum wool content. Moreover, part-wool textiles are often purchased on specifications requiring a definite wool content.

Several methods for the determination of cotton and wool in mixtures have been studied by the textile section of the Bureau. A report of this investigation showing the inadequacy of some of the methods and describing a satisfactory procedure will be published in the January issue of the *Bureau of Standards Journal of Research* as Research Paper no. 635. In the method recommended, sizing, finishing materials, and natural nonfibrous constituents of the textiles are removed by solvent extraction followed by digestion with a starch-hydrolyzing enzyme and washing. Wool is determined directly by weighing after removal of the cotton by carbonization with aluminum chloride. Cotton is determined directly by weighing after removal of the wool with potassium hydroxide. Results accurate within 1 per cent. of the amount of total dry fiber present are readily obtainable by this method.

LETTER CIRCULARS.[2]

LC395 Preparation and colorimetric properties of a magnesium-oxide reflectance standard.

[2] It is the intent of the Bureau to distribute single copies of these Letter Circulars on request only to those parties having special interest in the individual Letter Circular. Economy necessitates limitation in the number of copies issued. It is not the intent to supply parties with a copy of each letter circular issued during the month. Letter circulars are necessarily of a temporary nature designed to answer numerous inquiries on a given subject. Requests should be addressed to the Bureau of Standards, Washington, D. C.

LC396 Publications relating to textiles.

LC397 Can I save gas with a gas saver? (This applies to the use of so-called gas savers, attachable solid tops and other appliances, on cooking ranges.)

LC398 Publications on colorimetry and spectrophotometry from the Bureau of Standards.

LC399 Weights and measures publications of general interest. (Revision of LC243.)

LC400 Sources of radio information. (Revision of LC274.)

LC401 Railroad track scale testing service of the National Bureau of Standards, fiscal year July 1, 1932 to June 30, 1933.

The Bureau of Chemistry and the Farmer.—In the Bureau's annual report, Dr. Henry G. Knight, Chief, tells how his department is helping the farmer to grow and utilize his crops more efficiently and with greater profit. The department has developed a method of hastening color development in oranges which has recently increased the value of the Florida orange crop by making the fruit ready for an earlier market Research by the Bureau has resulted in the establishment of the citrus byproducts industry. Citrus growers now garner millions of dollars from culls which are used to make lemon oil, orange oil, and citrus pectin. It has been demonstrated that sweet potato starch satisfactorily replaces imported potato starch in cotton mills and now several sweet potato starch mills are under construction in the South.

Distillation tests conducted at Ames, Iowa, showed that yields of 100 pounds of acetic acid per ton from pecan shells and 130 pounds per ton from corn cobs could be obtained. Preliminary experiments have tested possibility of supplying the farmers of the prairie states with cheaper fuel by briquetting the farm waste. A farm unit pilot plant for the production of fuel gas has been installed to show whether it is practical to convert farm wastes and house sewage into light and heat for farm homes.

Bureau chemists have synthesized a derivative of rotenone, dehydrorotenone, which is more stable in sunlight. If the product can be developed as a satisfactory substitute for lead arsenate, it will save the apple growers the considerable expense of removing arsenic and lead residues from the fruit.

C.

THE FRANKLIN INSTITUTE

CELEBRATION COMMEMORATING THE THIRTIETH ANNIVERSARY

OF THE FLIGHT OF THE WRIGHT BROTHERS AT KITTY HAWK, NORTH CAROLINA, AND THE DEDICATION OF THE AVIATION SECTION OF THE MUSEUM OF THE FRANKLIN INSTITUTE, DECEMBER SIXTEENTH AND SEVENTEENTH, 1933.

On the evening of Saturday, December sixteenth, a dinner was held at the Bellevue-Stratford Hotel in honor of Dr. Orville Wright, the surviving one of the two Wright Brothers who made the memorable flight at Kitty Hawk thirty years ago.

At three-thirty on the afternoon of Sunday, December seventeenth, formal exercises were held in the hall of The Franklin Institute. The meeting was called to order by Nathan Hayward, President, who presided. In opening the meeting Mr. Hayward said:

"Today is the thirtieth anniversary of that world startling event, when on the lonely beach of North Carolina, Wilbur and Orville Wright raised their 'Flyer' into the air and traveled eight hundred feet before again touching the sand.

"We are celebrating this anniversary by dedicating the Aviation Section of The Franklin Institute Museum, which was made possible by the generosity of Townsend and Nicholas Ludington. Mr. Orville Wright has done us the great honor to come here to attend this dedication, and when we consider how many other groups of aviation fans were panting to have him with them this day, we may well feel proud of the compliment which he is paying us. His coming here is a sign of confidence in the undertaking of the Institute which should give us added courage and enthusiasm to make this exhibit an ever growing inspiration and aid to the art

and science of aviation. If we ever flag or hesitate, let us remember that Orville Wright had confidence in us at our start and let us be worthy of that confidence.

"We are very fortunate today in having with us a few of the men associated with the early days of aviation and still interested and active in the field of aviation. They have agreed to say a few words to give you a picture of this great science and art.

"I introduce first Mr. Frank H. Russell, who was the original manager of the Wright Brothers Company and who still is the President of the Manufacturers' Aircraft Association. He will speak to you on the significance of the anniversary."

MR. RUSSELL:

"About a year ago the government dedicated a monument at Kitty Hawk and that, as you know, has on the top of it a light which can be seen for miles and miles, both from the sea and from the land. But that light does not in any way emphasize the significance of the event which took place thirty years ago when the beginning of a new science began at that point.

"Some four or five hundred years ago, Jean Besnier tried to fly with wings. He did not make a success of it and during the succeeding four or five hundred years men have had the desire to fly but have not had the knowledge. Every decade has shown during that period some failure but always the idea was there, the objective was there, but it was never a success until the Wright Brothers forgot their kite and began to study gliding.

"Having collected all the information available, they began to experiment themselves and in 1902 they went down to Kitty Hawk to investigate all the country 'round about in the east to find a suitable location. They found a secluded spot and returned to Dayton and the following year built the first aeronautical motor and designed a plane to go with it.

"The motor weighed two hundred pounds and had twelve horse power. With that twelve horse power they built a plane of seven hundred and fifty pounds and took it down to Kitty Hawk.

"I am going to read now the story of his test as Mr. Wright

wrote it some years ago. In that way the facts will be presented.

HOW WE MADE THE FIRST FLIGHT*

BY ORVILLE WRIGHT

The flights of the 1902 glider had demonstrated the efficiency of our system of maintaining equilibrium, and also the accuracy of the laboratory work upon which the design of the glider was based. We then felt that we were prepared to calculate in advance the performance of machines with a degree of accuracy that had never been possible with the data and tables possessed by our predecessors. Before leaving camp in 1902 we were already at work on the general design of a new machine which we proposed to propel with a motor.

We decided to undertake the building of the motor ourselves. We estimated that we could make one of four cylinders with 4-inch bore and 4-inch stroke, weighing not over 200 pounds, including all accessories. The ability to do this quickly was largely due to the enthusiastic and efficient services of Mr. C. E. Taylor, who did all the machine work in our shop for the first as well as for the succeeding experimental machines.

While Mr. Taylor was engaged with this work, Wilbur and I were busy in completing the design of the machine itself. The preliminary tests of the motor having convinced us that more than 8 horse power would be secured, we felt free to add enough weight to build a more substantial machine than we had originally contemplated.

When the motor was completed and tested we found that it would develop 16 horse power for a few seconds, but that the power rapidly dropped till, at the end of a minute, it was only 12 horse power. Ignorant of what a motor of this size ought to develop, we were greatly pleased with its performance. More experience showed us that we did not get one-half of the power we should have had.

With 12 horse power at our command, we considered that we could permit the weight of the machine with operator to rise to 750 or 800 pounds and still have as much surplus power

* From an article in December, 1933, issue of *Flying*.

as we had originally allowed for in the first estimate of 550 pounds.

We left Dayton, September 23d, and arrived at our camp at Kill Devil Hill on Friday, the 25th. We found there provisions and tools, which had been shipped by freight several weeks in advance. The building, erected in 1901 and enlarged in 1902, was found to have been blown by a storm from its foundation posts a few months previously. While we were waiting the arrival of machinery and parts from Dayton, we were busy putting the old building in repair, and erecting a new building to serve as a workshop for assembling and housing the new machine.

Just as the building was being completed, the parts and material for the machines arrived simultaneously with one of the worst storms that had visited Kitty Hawk in years. The storm came on suddenly, blowing 30 to 40 miles an hour. It increased during the night, and the next day was blowing over 75 miles an hour. In order to save the tar-paper roof, we decided it would be necessary to get out in this wind and nail down more securely certain parts that were especially exposed. When I ascended the ladder and reached the edge of the roof, the wind caught under my large coat, blew it up around my head and bound my arms till I was perfectly helpless. Wilbur came to my assistance and held down my coat while I tried to drive the nails. But the wind was so strong I could not guide the hammer and succeeded in striking my fingers as often as the nails.

The first run of the motor on the machine developed a flaw in one of the propeller shafts which had not been discovered in the test in Dayton. The shafts were sent at once to Dayton for repair, and were not received again until November 20, having been gone two weeks. We immediately put them in the machine and made another test. A new trouble developed. The sprockets, which were screwed on the shafts and locked with nuts of opposite thread, persisted in coming loose. After many futile attempts to get them fast, we had to give up for that day, and went to bed much discouraged. However, after a night's rest, we got up the next morning in better spirits and resolved to try again.

While in the bicycle business we had become well ac-

quainted with the use of hard tire cement for fastening tires on the rims. We had once used it successfully in repairing a stop watch after several watchsmiths had told us it could not be repaired. If tire cement was good for fastening the hands on a stop watch, why should it not be good for fastening the sprockets on the propeller shaft of a flying machine? We decided to try it. We heated the shafts and sprockets, melted cement into the threads and screwed them together again. This trouble was over. The sprockets stayed fast.

On November 28th, while giving the motor a run indoors, we thought we again saw something wrong with one of the propeller shafts. On stopping the motor we discovered that one of the tubular shafts had cracked!

Immediate preparation was made for returning to Dayton to build another set of shafts. We decided to abandon the use of tubes, as they did not afford enough spring to take up the shocks of premature or missed explosions of the motor. Solid tool-steel shafts, of smaller diameter than the tubes previously used were decided upon. These would allow a certain amount of spring. The tubular shafts were many times stronger than would have been necessary to transmit the power of our motor, if the strains upon them had been uniform. But the large hollow shafts had no spring in them to absorb the unequal strains.

Wilbur remained in camp while I went to get the new shafts. I did not get back to camp again till Friday, the 11th of December. Saturday afternoon the machine was again ready for trial, but the wind was so light a start could not have been made from level ground with the run of only sixty feet permitted by our monorail track. Nor was there enough time before dark to take the machine to one of the hills where, by placing the track on a steep incline, sufficient speed could be secured for starting in calm air.

Monday, December 14th, was a beautiful day, but there was not enough wind to enable a start to be made from the level ground about camp. We therefore decided to attempt a flight from the side of the big Kill Devil Hill. We had arranged with the members of the Kill Devil Life Saving Station, which was located a little over a mile from our camp, to inform them when we were ready to make the first trial

of the machine. We were soon joined by J. T. Daniels, Robert Westcott, Thomas Beachem, W. S. Dough and Uncle Benny O'Neal of the Station, who helped us get the machine to the hill, a quarter mile away. We laid the track 150 feet up the side of the hill on a 9-degree slope. With the slope of the track, the thrust of the propellers and the machine starting directly into the wind, we did not anticipate any trouble in getting up flying speed on the 60-foot monorail track. But we did not feel certain that the operator could keep the machine balanced on the track.

When the machine had been fastened with a wire to the track, so that it could not start until released by the operator, and the motor had been run to make sure that it was in condition, we tossed up a coin to decide who should have the first trial. Wilbur won. I took a position at one of the wings, intending to help balance the machine as it ran down the track. But when the restraining wire was slipped, the machine started off so quickly I could stay with it only a few feet. After a 35- to 40-foot run it lifted from the rail. But it was allowed to turn up too much. It climbed a few feet, stalled, and then settled to the ground near the foot of the hill, 105 feet below. My stop watch showed that it had been in the air just 3½ seconds. In landing, the left wing touched first. The machine swung around, dug the skids into the sand and broke one of them. Several other parts were also broken, but the damage to the machine was not serious. While the test had shown nothing as to whether the power of the motor was sufficient to keep the machine up, since the landing was made many feet below the starting point, the experiment had demonstrated that the method adopted for launching the machine was a safe and practical one. On the whole, we were much pleased.

Two days were consumed in making repairs, and the machine was not ready again till late in the afternoon of the 16th. During the night of December 16, 1903, a strong, cold wind blew from the north. When we arose on the morning of the 17th the puddles of water, which had been standing about camp since the recent rains, were covered with ice. The wind had a velocity of 10 to 12 meters per second (22 to 27 miles an hour). We thought it would die down before

long and so remained indoors the early part of the morning. But, when ten o'clock arrived, and the wind was as brisk as ever, we decided that we had better get the machine out and attempt a flight. We hung out the signal for the men of the life saving station. We thought that by facing the flyer into a strong wind there ought to be no trouble in launching it from the level ground about camp. We realized the difficulties of flying in so high a wind, but estimated that the added dangers in flight would be partly compensated for by the slower speed in landing.

We laid the track on a smooth stretch of ground about 100 feet north of the new building. The biting cold wind made work difficult, and we had to warm up frequently in our living room where we had a good fire in an improvised stove made of a large carbide can. By the time all was ready, J. T. Daniels, W. S. Dough and A. D. Etheridge, members of the Kill Devil Life Saving Station, W. C. Brinkley, of Manteo, and Johnny Moore, a boy from Nag's Head, had arrived.

Wilbur, having used his turn in the unsuccessful attempt on the 14th, the right to the first trial now belonged to me. After running the motor a few minutes to heat it up, I released the wire that held the machine to the track, and the machine started forward into the wind. Wilbur ran at the side of the machine, holding the wing to balance it on the track. Unlike the start on the 14th, made in a calm, the machine, facing a 27-mile wind, started very slowly. Wilbur was able to stay with it till it lifted from the track after a forty-foot run. One of the life saving men snapped the camera for us, taking a picture just as the machine had reached the end of the track and had risen to a height of about two feet. The slow forward speed of the machine over the ground is clearly shown in the picture by Wilbur's attitude. He stayed along beside the machine without any effort.

The course of the flight up and down was exceedingly erratic, partly due to the irregularity of the air, and partly to lack of experience in handling this machine. The control of the front rudder was difficult on account of its being balanced too near the center. This gave it a tendency to turn itself when started, so that it turned too far on one side and then too far on the other. As a result, the machine would rise

suddenly to about ten feet and then as suddenly dart for the ground. A sudden dart when a little over a hundred feet from the end of the track or a little over 120 feet from the point at which it rose into the air, ended the flight. As the velocity of the wind was over 35 feet per second and the speed of the machine over the ground against this wind ten feet per second, the speed of the machine relative to the air was over 45 feet per second, and the length of the flight was equivalent to a flight of 540 feet made in calm air. This flight lasted only 12 seconds, but it was nevertheless the first in the history of the world in which a machine carrying a man had raised itself by its own power into the air in full flight, had sailed forward without reduction of speed, and had finally landed at a point as high as that from which it started.

At twenty minutes after eleven Wilbur started on the second flight. The course of this flight was much like that of the first, very much up and down. The speed over the ground was somewhat faster than that of the first flight, due to the lesser wind. The duration of the flight was less than a second longer than the first, but the distance covered was about 75 feet greater.

Twenty minutes later the third flight started. This one was steadier than the first one an hour before. I was proceeding along pretty well when a sudden gust from the right lifted the machine up twelve to fifteen feet and turned it up sidewise in an alarming manner. It began a lively sliding off to the left. I warped the wings to try to recover the lateral balance, and at the same time pointed the machine down to reach the ground as quickly as possible. The lateral control was more effective than I had imagined, and before I reached the ground the right wing was lower than the left and struck first. The time of this flight was fifteen seconds and the distance over the ground a little over 200 feet.

Wilbur started the fourth and last flight at just 12 o'clock. The first few hundred feet were up and down as before, but by the time 300 feet had been covered, the machine was under much better control. The course for the next four or five hundred feet had but little undulation. However, when out about 800 feet the machine began pitching again, and in one of its starts downward struck the ground. The distance over

the ground was measured and found to be 852 feet; the time of the flight, 59 seconds. The frame supporting the front rudder was badly broken, but the main part of the machine was not injured at all. We estimated that the machine could be put in condition for flight again in a day or two.

While we were standing about discussing this last flight, a sudden strong gust of wind struck the machine and began to turn it over. Everybody made a rush for it. Wilbur, who was at one end, seized it in front, Mr. Daniels and I, who were behind, tried to stop it by holding to the rear uprights. All our efforts were vain. The machine rolled over and over. Daniels, who had retained his grip, was carried along with it, and was thrown head-over-heels inside of the machine. Fortunately he was not seriously injured, though badly bruised in falling about against the motor, chain guides, etc. The ribs in the surfaces of the machine were broken, the motor injured and the chain guides badly bent, so that all possibility of further flights with it for that year were at an end.

"The boys had completed the first flight in the history of the world and they got back to Dayton for Christmas. From that time on, they devoted their lives to the history of aviation.

"Books have been written as a result of their achievement. Here it will suffice to say that one seldom meets a person today who has not had a flight; that many use the airplane entirely; commercial airlines carry persons and things to all parts of the civilized world; that our redoubtable colonel and his wife have visited three continents and are back home in time for Christmas; that every nation has an air force; that the airplane is not a game and a luxury but an industry and a necessity.

"It is significant when one realizes that when you examine any one of these modern machines it has some elements of control that were discovered by the Wright Brothers and first used at Kitty Hawk in 1903. Their work was done; the development was left to others. It is quite evident, however, that the character of the Wright Brothers has left its mark on aviation. Men—unselfish; always loyal to each other; always working with a definite plan; always busy; never hurried but

always sure—their character has impressed itself upon every man who flies.

"Mr. Wright, I want to express to you the appreciation and the gratitude that we feel for you and to the memory of your brother."

MR. HAYWARD:

"Colonel Paul Henderson is next going to speak to us on 'The Airplane in Transportation.' I am not going to try to give an outline of his work but I can assure you that his experience makes him a very suitable person to discuss this subject.—Colonel Henderson."

COL. PAUL HENDERSON:

Mr. Chairman, Ladies and Gentlemen, and Mr. Orville Wright:

Mr. Wright, I am sure that thirty years ago today, when at Kitty Hawk, you and your brother accomplished what you did, you were wholly unconscious of the fact that your achievement of that day would influence the lives, the habits and the activities of many individuals here in America today. I am sure that your thought was all centered on the scientific and practical aspects of your problem. Nevertheless, I for one have had my life arranged for me by the action of you and your brother, at least insofar as the last decade is concerned. Sometimes I feel very grateful to you for the influence which your achievements have had in shaping my activities for the past ten years. I must admit that there are days, however, when I feel almost sorry that you were able to accomplish what you did on that memorable day at Kitty Hawk. Those are the days when my problems seem insurmountable.

Aviation, which you created, has become complicated, just as modern life is complicated.. Aviation has become a business. Aviation has become an integral part of the armament, both offensive and defensive, of our country. Aviation has become an accepted method of transportation. With these changes of the last thirty years all growing out of your work, have naturally come perplexing problems of business, government, finance and technique. It would be

too much to hope that all of us who owe our work-a-day lives to your genius would find all of our tasks pleasing ones, so that when I say that sometimes I almost regret that you were successful at Kitty Hawk, you will understand that the mood of certain moments grows out of my lack of ability to see clearly through some of the problems that occasionally find themselves on my desk.

Speaking more directly to the point, I feel that I owe you a very deep debt of personal gratitude. No matter what the future may have in store for aviation as a business, no matter what financial success or disappointment may surround those efforts with which I am identified, nothing can take away from me the great pleasure that I have had since 1922 struggling with the problem of adapting to our every-day lives first, the commonplace job of mail-carrying; second, the more complicated job of passenger carrying, this new vehicle which was born of your hand and brain and the hand and brain of your revered brother at Kitty Hawk thirty years ago today.

There is none of us in aviation who does not regret that your brother did not live to share with you through all these years the honor which you and he earned on that day. I am sure that the world when it pays tribute to you and to your brother, Wilbur, realizes that it must concentrate through you the honor, respect and gratitude which it would like to have shared between you and your brother.

Your accomplishment did not end on the sand at Kitty Hawk. Every time there is a new aeronautical record established, whether it be for speed or altitude or endurance, every time an air line in America or in Europe makes a new record for volumes of cargo carried, numbers of passengers carried, it is after all your work reflected through the years. Every aeronautical combat in the great war was a lasting monument to your continued success through the years after Kitty Hawk.

Your accomplishment has made possible the building of a marvelous technique. Today there are hundreds of young men in America thoroughly trained in those principles of engineering for which you laid the foundation thirty years ago. Their work would not be possible, their accomplishments would be negative were they not all based on the

fundamentals which you not only discovered but proved when you and your brother startled the world in 1903.

I take no small amount of satisfaction out of the fact that it has been my privilege to play a part, modest as that part has been, in the adaptation of your discovery to a work-a-day job of transportation. When, in 1922 I found myself faced with the responsibility of the transportation of United States mails, and when I found that among other things it had become my duty to administer the air mail, I must admit that I was for the moment shocked. I discovered that there was some million and a half dollars at my disposal for the first year's operation of air mail under my direction. I had reached that age in life when I had a very wholesome respect for a million dollars, and I am going to confess to you now that it seemed to me on first inspection that there was at least one service that I could perform to justify the President having appointed me as an Assistant Postmaster General. It seemed to me that I could at least discontinue the air mail service and return the million and a half dollars to the Treasury. Fortunately, I reached those conclusions in the privacy of my bed chamber, and conveyed them to nobody except myself until I had opportunity to look into the subject and discover for myself just what manner of thing an airplane was and just what, if any value, it might have in the prosaic job of carrying mail across the country. I found the airplanes which were then being used in the postal service carried loads which when compared to loads carried on the surface were insignificant. I found that although they flew rather rapidly, they weren't able to operate at night; and that except in fair weather, their regularity was anything but pleasing. After looking around, talking to a few who had real experience in the art of flying, and holding secret conferences with myself, I decided that I would put the air mail service to a test. I decided that if we could conceive some plan which would permit us to fly at night, we might change the picture; we might introduce a factor that would give the airplane, despite its limitations, a real place in postal affairs. There were very few even in the flying fraternity who were willing to give encouragement. Those few who were encouraging in their advice, although greatly outnumbered by those who

took the opposite view, were so intelligent in their optimism that I decided to follow the few and disregard the many. You are familiar with the work which was done to prove whether or not night flying could be accomplished. It took us sixteen months to get ready to try it. I must admit that during those sixteen months my conscience frequently disturbed me. My Scotch blood frequently suggested to me—"Stop this foolishness and put what is left of this money back in the Treasury," but either my curiosity or my optimism got the better of my frugal nature, and we went ahead. We did fly successfully at night. From then on, even my Scotch conscience about money was lulled to sleep with the prospect of practical application which unfolded itself. The rest of the history of air mail needs no repetition. It has grown by leaps and bounds. It has earned great and enthusiastic reception into the lives, business and social, of our people. It will never be destroyed. Each year air mail will be better, faster, more certain and more important in our modern lives. Each year from now forward more and more people will depend upon aircraft for their regular work-a-day transportation from place to place. We will fly faster, safer, and with more regularity as time goes on.

For all of this you are responsible. Like all business, we have our problems for which you are not responsible. I am sure that none of us engaged in this most interesting effort ever permits himself to forget the moral obligation which we as individuals, which our country as a nation, and which the commercial life of our country owe to you and to your brother.

Not the least of your accomplishments, Mr. Wright, in my opinion, is the manner in which you have lived your life during the last ten of these thirty years, during which it has been my privilege to know you. Your modesty, steadiness and helpfulness is an inspiration to all who know you and your methods. Your name means much throughout the world. It has never been tarnished. It, because first of your great achievement, and second; because of your modest demeanor, stands as a perpetual monument not only to you but to your illustrious brother.

I wish it were within my ability to find more fitting words to express my admiration of you.

The United Air Lines, of which company I happen to be an officer, has chosen today—your anniversary day—upon which to inaugurate its first service into this Philadelphia community—today, and from now forward we are connecting Philadelphia by air, using your vehicle, with Cleveland, Chicago and the great west. Today Chicago is 4½ hours from Philadelphia—San Francisco 19½ hours. This is not our accomplishment—it is yours—30 years in the making.

MR. HAYWARD:

"Lieutenant Harrison of the U. S. Navy, who represents our Navy Yard, which has been so generous and helpful in making possible the exhibits which you will see in a few moments, will now speak to us on "Engineering Structures in Aviation."

LIEUT. LLOYD HARRISON:

Mr. President, Doctor Wright, Ladies and Gentlemen:

In discussing the subject "The Part of Engineering Structures in Aircraft," the engineer, who deals regularly with figures and calculations, tends to give some sort of a statistical review of the comparative weights and percentages of various components of the aircraft in the attempt to indicate what part in progress the work of the engineer has played. Such a method runs into some objections when it attempts to portray the actual history of aeronautical progress, because the figures to demonstrate the progress must, of course, be selected out of a great number and an audience realizes that by means of such a selection a rather false picture can readily be made—as the saying goes "Statistics always lie." Furthermore, after the presentation of such a group of figures, particularly in view of such ones as I shall quote shortly, the engineer who attempts to tell in detail how much weight has been saved by this refinement here or that refinement there is more or less in the position of the exceedingly stout person who by dint of strenuous exercises has accomplished some reduction in weight and goes about telling his acquaintances about the details thereof. Of course, after he has told how he has lost

a few pounds here by this bending exercise and a few pounds there by that rolling exercise and comes to an end, the acquaintances are led to remark, "Well, you still seem pretty fat to me."

Accordingly instead of giving you a thorough statistical review I propose instead to give you a typical definition of an airplane and then by my data to indicate how this definition gives a deceptive idea of the problem of the engineer in aircraft design and to suggest a somewhat expanded definition which will perhaps more clearly indicate the engineer's problem.

The definition I shall first set up is that proposed by a British wing designer in a paper read before the Royal Aeronautical Society about a year ago in approximately the following language: "The fundamental elements of an airplane are the wings which by their lift enable it to sustain the dead weight, and the engine which enables the machine to rise from the ground and progress through the air at a speed sufficient to give the wings the required lift. The remainder of the airplane represents our inability to design an efficient airplane. The landing gear is employed because we insist upon a long run on a nice, expensive airport. The fuselage is employed because we will not put the passengers in the wings which are already available and in order to support the tail, which is required to provide control to offset an inefficient wing section."

A consideration of some very general data in connection with airplanes gives a hint at once of the inadequacy of this definition. The 750 pounds or so of gross weight of the Kitty Hawk airplane of thirty years ago had its weight divided roughly into thirty per cent. power plant, forty-five per cent. structure and twenty-five per cent. useful load. The high performance airplanes of our present day have weight balances of almost precisely these percentages, in some cases, and even the typical average airplane does not depart greatly from them—having perhaps twenty-five per cent. power plant, thirty-five per cent. structure and forty per cent. useful load. It is obviously unreasonable to think that in these thirty years of progress the various specialists have been unable to make anymore appreciable advance than these figures indicate, when today we have engineers working on every

feature of aircraft design, whereas for the Kitty Hawk plane the Wright Brothers had not only to conceive the airplane but also to develop the engine and the propeller, to design the structure, and finally to fly the plane. As a matter of fact, the efforts of aeronautical engineers in this intervening period have left their traces in fields quite apart from the airplane; for example, those of you who go away from this auditorium to return to your homes by high speed electric transit will find your progess more rapid on account of the employment in modern railway cars of light alloys of aluminum, developed originally for airplane use, and similar examples of this sort could be multiplied in great number.

Where, then, has this engineering progress hidden its results? An indication can be attained from considering the relative effects of weight saving upon carrying capacity and upon performances. If only a saving of one-tenth in the structural weight of the airplane were made an increased pay load of about one-seventh could be carried in a typical commercial airplane. If, however, a saving of fully two-thirds of the structural weight were made—quite an impossible saving in the present state of the art—the effect upon performance would be of a much reduced character. The landing speed might be reduced ten per cent., the high speed might be increased less than five per cent., and the principal effect would be noticed in an increased ability to climb. That is, slightly better performance requires very great improvement in the engineering elements.

Actually the engineering progress has been most considerable. Taking for example the matter of wing weights alone, a few comparisons may be interesting. The Delaware River Bridge was designed for live loads of 200 pounds per square foot and weighs 400 pounds per square foot. The floors of a building of the character of the one in which we are meeting are designed for loads of 100 or 120 pounds per square foot and weigh from 50 to 100 pounds per square foot. The wings of the early airplanes carried loads of approximately 5 pounds per square foot and weighed ½ a pound per square foot. On the other hand, some of our later high performance airplanes carry ultimate strength wing loadings of 180 pounds per square foot and weigh 1½ pounds

per square foot. Taking into account relative factors of safety and other appropriate considerations, we get ratios of strength-weight efficiency in these various cases of one for the bridge, approximately four for the building, ten for the original airplanes and one hundred and twenty for the latest airplane types; that is, the airplane is structurally now approximately one hundred and twenty times as efficient as the bridge and twelve times as efficient as the earliest airplanes.

However, due to the small relative effect of improved structural efficiency upon performance it has proved the case that these tremendous developments and similar improvements in engine performances and in aerodynamic efficiency have lost themselves easily in improved overall performance of the airplane, principally in high speed, which as we all know has been increased from five to ten fold, and is the outstanding feature of the airplane. It would be possible now-a-days to design an aircraft which could pick up tons of coal from the elevators at Girard Point and carry them at speeds as low as twenty miles an hour over this city, deposit them at destinations and return to Girard Point for other loads. Of course, this is not done. It would be too expensive. The field of the airplane is principally the field of high speed travel and it has been in attaining the proper development in this field that the airplane has improved as an engineering structure.

In conclusion, it is proper to point out that our original definition of an airplane as wings and engine, simply a flying machine, was as well satisfied by the first successful airplane as by all its later developments. The improvement of the airplane has been in the direction of fitting a special field. The airplane is now designed to afford transportation of a useful or pay load of passengers, freight or military equipment, so speedy, efficient, reliable and agreeable that its service will be in such demand that the pay load will be offered for transportation in such quantity that the operation of the airplane will be profitable and it will earn its construction cost and its keep. The airplane is now more than a flying machine, it is a useful and profitable instrument of commerce and war, become so in considerable part because it is primarily a refined engineering structure.

MR. HAYWARD:

"No meeting of any kind on any subject is really successful in The Franklin Institute unless we have our Secretary and Director say something. What he is going to say, I do not know, but I assure you from long experience that it will be well said."

TRIBUTE TO MR. WRIGHT.

By DR. HOWARD MCCLENAHAN.

Today we have heard very gratefully of the life which Mr. Wright has led during the last thirty years. I would like to bear direct testimony to the character of that life. I went to Dayton about two years ago to see Mr. Wright and was having breakfast on the morning of my first day in that city; it was also my first visit. One of the blackest of Ethiopians was serving me. I said to him, "Boy, can you tell me where Mr. Wright lives?"

"No, boss, 'deed I can't."

"Don't you know where he lives?"

"No, boss, 'deed I doesn't."

"Do you know who Mr. Orville Wright is?"

"No, boss, I can't say I do."

And I said, "Well, I will tell you" and proceeded to tell him who Mr. Orville Wright is.

Whereupon the young man exclaimed, "Well, you see, boss, dat dere man don't come to our night clubs and I don't know anything about him."

I wish it were possible for us to have a talk from Mr. Wright today. It is not possible, for his physician has directed that he shall not talk. We want him here in health and to enjoy this occasion and he has been told that he may not make a speech but he has been told that we want him to arise and stand before us so that we may see this fine young man who had a dream and made that dream come true. (When Mr. Wright arose the entire audience arose likewise and applauded for several minutes.)

Ladies and gentlemen, this is a richly deserved tribute to the man who has brought about not merely the art but also the science of aviation, for Mr. Wright, with his brother

Wilbur, laid the foundation for the science of aviation as well as for the art of flying. We think he developed the Kitty Hawk plane largely as a matter of experimentation. The design was based upon very accurate mechanical determinations of a most scientific character, and so Mr. Wright is not only the pioneer in flight but is largely the man who has laid the fundamentals of the accumulation of scientific data on aviation. We do well to pay honor to him and to his brother for this achievement.

MR. HAYWARD:

"Ladies and gentlemen, we are now going to adjourn in a body to the Aviation Section of our new museum.

The meeting reconvened in the Aviation Section of the museum of The Franklin Institute where the most prominent exhibit is the airplane of Miss Emelia Earhart in which she made her solo flight to Europe.

MR. HAYWARD:

"I have spent the last two days in gathering information regarding men and women who have dedicated their lives to the service of aviation. We have all heard of the trip across the ocean by a young girl but few of us realize, I believe, the rigorous training which was necessary to accomplish this feat. For months and even years from the time Amelia Earhart conceived the idea of making such a trip, she had trained to accomplish the known results. This training was mental as well as of an intensely physical nature. When we dedicate this room, we do not want to forget the courage which made her flight possible. Let us always remember that the important thing was her character which kept her during months and years preparing for her notable achievement."

Standing beneath her plane, Miss Earhart dedicated the Hall of Aviation to the dissemination of knowledge of that science. She spoke as follows:

MISS AMELIA EARHART:

This afternoon we have heard the colorful tale of the beginnings of flight and we have seen and have been close to one of the men who is responsible for that great achievement. The history of aviation confirms the hopes that came out of Kitty Hawk thirty years ago. Chapter Two is the history of the fledgling and its gain in strength and speed and new wings have become an integral part of modern transportation. The plane above me is an example of modern aircraft. A year and a half ago lacking one day it carried me across the Atlantic. I left New York and went to Newfoundland and from there to Ireland. I want only to say that this flight added little to aviation, for hundreds of people had already crossed, and literally hundreds have crossed, so that one flight more or less does not add much to that startling sum total. This plane had done considerable flight before that flight. It was three years old at the time. It also holds the women's distance record of twenty-six hundred miles for a non-stop flight. It is needless to say that it is a creature which holds my deep interest and affection as does its brothers of the past, the present and the future.

In dedicating this Hall this afternoon I hope that those who come to see the exhibits shall not forget in the ubiquity of airplanes the spirit which conceived it and the beauty of flight itself which the Wright brothers opened to mankind.

DR. MCCLENAHAN:

"Ladies and gentlemen, there is nothing to add to this charming statement of Miss Earhart but one thing: We accept the challenge of her flight and the challenge implied in her statement. The Franklin Institute dedicates itself, through this room which has been so generously donated to us, to the extension and dissemination of knowledge of the science of aviation among the young people of this community. We thank you all for coming here today and wish to express our appreciation of your interest which is manifested by your presence.

"The meeting is adjourned."

PROCEEDINGS OF THE ANNUAL MEETING HELD WEDNESDAY, JANUARY 17, 1934.

The annual meeting of the Institute was called to order at eight-fifteen P.M. on Wednesday, January seventeenth, by W. C. Wetherill, Vice-President, in the absence of the President of the Institute. The Chairman immediately called upon the Secretary for the business of the meeting.

The Secretary first announced that the minutes of the December meeting of the Institute had been printed in full in the Journal of the Institute for January and moved that the minutes be approved as printed. This motion was adopted unanimously and the minutes were declared approved.

The Secretary then announced the results of the annual election of officers and members of the Board of Managers as follows:

President (To serve one year)	Nathan Hayward
Vice-Presidents (To serve one year)	Henry Howson
	C. C. Tutwiler
	Walton Forstall
	W. Chattin Wetherill
Treasurer (To serve one year)	Benjamin Franklin
Managers (To serve three years)	Francis T. Chambers
	Charles H. Ewing
	Samuel S. Fels
	W. W. Fry
	Robert W. Lesley
	Horace P. Liversidge
	Malcolm Lloyd, Jr.
	Marshall S. Morgan
(To serve one year)	Samuel M. Vauclain

The Chairman then announced that the gentlemen, whose names had been read, were elected to the several offices.

The Secretary requested that a vote of thanks be given on behalf of the Institute to the Tellers in appreciation of their services. The Tellers were: Mr. W. N. Jennings, Dr. Walter T. Taggart and Mr. W. F. Denkhaus.

The secretary then stated that it was his duty as Director of The Benjamin Franklin Memorial and The Franklin Institute to make a brief summary of the activities of the Institute during the past year. He stated that the most important event of the year, of course, was the occupation of the new building by the Institute, which began on November first and was completed just before the close of the last year. He called to the attention of the meeting the room in which the meeting was held, pointed out its characteristics and referred briefly to the other features of the building. He invited the public at large to visit the building and to enjoy the interesting things which were displayed in it.

He made reference to the meeting held on November twenty-third in the old Institute building, which was the last meeting to be held in that building and which was of the nature of a commemoration of the services done by The Franklin Institute to the community and the nation while housed in the old building. This meeting, on November twenty-third, was addressed solely by old members of the Institute, who could speak with authority of its past, and by the Secretary, who spoke of the plans for the future.

The speaker further stated that the established departments of the Institute, the Library, the Committee on Science and the Arts, the Lectures, the Journal, the Christmas Week Lectures, the Bartol Research Foundation, all have been carried on with marked success during the past year. The remarkable work of the Bartol Research Foundation has been carried on with increasing success and has given to that laboratory a most enviable reputation among scientists. The activities of the other old departments have been highly successful in character as well. With reference to the new departments of the Institute, it was stated that the planetarium was opened to the public on November sixth and the museum of the Institute on January first. Since November sixth, approximately eighty-six thousand people have visited the new building and in a large number of cases have expressed themselves as delighted and stimulated by the new institution.

With reference to the Membership of the Institute, the Secretary announced that there had been a gratifying increase in the membership, especially among Student Members. He then made a statement concerning the new types of Museum Membership in The Institute which are being established.

The Secretary referred with sincerest regret to the deaths of those of great influence in the affairs of the Institute during the last year, especially to the deaths of three of the members of the Board of Managers, Mr. Cyrus H. K. Curtis, Mr. Elisha Lee, and Mr. Haseltine Smith.

Finally, the Secretary took advantage of the opportunity to express the hearty appreciation of all concerned of the splendid cooperation offered by the members of the Board of Managers, the members of the Staff, the members of The Franklin Institute and the generous friends who have collaborated in making this huge project the splendid success that it is.

There was no further business, whereupon the Chairman of the meeting presented as the speaker of the evening Mr. Henry Wright of New York City who spoke on "Housing Conditions." Mr. Wright outlined in a very interesting fashion the changing methods used in the construction of buildings of the resident type and indicated his conception of the requirements which must be fulfilled by such structures. His talk was followed by the asking of many questions and some discussion.

The meeting adjourned at nine-fifty P.M. with a rising vote of thanks to the speaker of the evening.

HOWARD MCCLENAHAN,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, January 10, 1934.)

HALL OF THE COMMITTEE,
PHILADELPHIA, JANUARY 10, 1934.

MR. THEOBALD F. CLARK *in the Chair.*

The following report was presented for final action:

No. 2951: Measuring Weight and Moisture Content of Sheet Materials.

This report recommended the award of the Certificate of Merit to Mr. Albert Allen, of Winchester, Massachusetts, "In consideration of the development of a system for continuously controlling the specific weight of sheet material in production."

The following reports were presented for first reading:

No. 2974: Vertical Antenna for Radio Transmission.

No. 2977, No. 2978 } Franklin Medal.

GEO. A. HOADLEY,
Secretary.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, January 17, 1934.)

RESIDENT LIFE MEMBERSHIP.

MRS. CHARLES F. GRIFFITH, Sculptor, Ardmore, Pa.

RESIDENT.

MR. ARMIN JOSEPH KRAUS, Research Chemist, E. F. Houghton and Company. For mailing: LaSalle Apt., Twelfth and Lindley Avenue, Philadelphia, Pa.

MR. EUGENE J. NATHAN, Equipment Engineer, Long Lines Relation, Bell Telephone Company, Philadelphia, Pa. For mailing: 1928 West Erie Ave., Philadelphia, Pa.

MR. CHARLES W. REISSE, Electrical Engineer, 5366 Wingohocking Terrace, Philadelphia, Pa.

MR. ROWE STEWART, Advertising, Stewart and Jordon, Philadelphia, Pa.

MUSEUM MEMBERSHIP:

FAMILY.

DR. ABRAHAM HENWOOD, Teacher, Central High School, Philadelphia, Pa. For mailing: 306 Kent Road, Bala-Cynwyd, Pa.

MRS. CARROLL HODGE, Radnor, Pa.

MRS. HAROLD LICHTEN, Germantown, Pa.

INDIVIDUAL.

MRS. JAMES STOKLEY, Alden Park Manor, Germantown, Pa.

STUDENT.

MR. FRED J. BAUM, JR., 98 East Ashmead Street, Germantown, Pa.
MR. WILLIAM H. BAVE, JR., 817 East Dorset Street, Philadelphia, Pa.
MR. AARON J. BLUMBERG, 2815 Wharton Street, Philadelphia, Pa.
MR. GEORGE DERNOEDEN, 521 North Creighton Street, Philadelphia, Pa.
MR. BAXTER EAVES, 265 South Hirst Street, Philadelphia, Pa.
MR. CURTIS R. GLENN, Bryn Athyn, Pa.
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MR. DUDLEY WILLCOX, Box 877, Trenton, N. J.
DR. WILLIAM WILSON, 463 West Street, New York City, N. Y.

NECROLOGY.

Mr. George Harrison Frazier, Philadelphia, Pa.

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BOOK REVIEWS.

THE INVENTOR AND HIS WORLD, by H. Stafford Hatfield, D.Sc., Ph.D. (London), 269 pages, 12.5 × 19 cms. New York, E. P. Dutton & Co., 1933. Price $2.40.

Sometimes it is exceedingly difficult to determine what inspires a book. It may be a jewel of an idea that glows and sparkles until bound. It may be looking into the up-turned faces of a class—if students ever so incline to the professor—or it may be a course of lectures dusted off for the general public. I rather think the "Inventor and His World" was written for the benefit of inventors fumbling about England for business partners.

At all events the book contains much side comment on the hapless lot of the hapless genius, a few hints on how to pull the leg gently but firmly of the business man and final wisdom on patent law. It suffers from British literary phlegm. There are a few redeeming passages. Very great praise for the light that burned inside the brain of Thomas Alva Edison, the genius of Mazda. The supreme theft of an idea is described by the author as "the most flagrant being the way in which the American Fulton stole the idea of the steamboat from a Scotsman named Symington, who took him for a trip on the first steamboat ever made." I presume that "the American Fulton" was Robert Fulton whose crime has escaped the recording of the Encyclopædia Britannica. Even the honest Symington is not mentioned but the Duke of Bridgewater, Earl Stanhope and James Watt are tested as acquaintances of his English stay. Apparently the idea was carried to Paris (where almost anything might happen). It was there that Fulton succeeded in propelling a boat by steam power in 1803. As much care is required in describing the heartburns of inventors as in drawing up letters patent.

The last chapter is devoted to useful information on patents. The budding inventor can read this part of the book with especial profit, as well as others who may have to do with the British Patent Office or "Convention" countries. The rights of intellectual property, Geistiges Eigentum, are of increasing importance

There is a good bibliography and few illustrations to illumine the text. One bit of poetry sets off the prose. The good, great, "grey" poet from Mickle Street, Camden, N. J., wins the horse show of thistledown. Speaking of the drift from the intellect of animals he quotes:

"They do not sweat and whine about their condition.
They do not lie awake in the dark and weep for their sins.
They do not make me sick discussing their duty to God,
. . . . . .
Not one is respectable or unhappy over the whole earth."

Q.E.D. "We are obliged to admit that a negation of industrial civilization is a negation of the course taken by humanity in all its past evolution" (page 53). Are we?

H. W. ELKINTON.

ATMOSPHERIC ELECTRICITY, by B. F. J. Schonland, preface by O. W. Richardson, 100 pages, diagrams, 11 × 17 cms. New York, E. P. Dutton & Co., Inc. Price $1.10.

This is an extremely interesting miniature compendium on a condition of our environment. So intimate is it that we hardly are conscious of it until an abnormal state (lightning) occurs. Normally, atmospheric electricity is quite unobtrusive and lives in a state of static balance. On the contrary, the equilibrium arises from forces in dynamic opposition.

Since Penetrating Radiation is responsible for a large proportion of the atmospheric ions, a complete chapter is given over to a discussion of the nature and the effects produced by these cosmic rays. Under the heading of "Electric Fields and Electric Currents in the Atmosphere" the author describes methods for determining the density of charge on the earth's surface as well as the potential gradient of the atmosphere in fair weather and under conditions of storm.

It is rather interesting to learn that the earth experiences close to 44,000 thunderstorms per day. This means that about 100 lightning flashes occur over the earth in every second. This final chapter on the Electrification of Thunderstorms discusses quite thoroughly the mechanism of building up those electric charges which must, a few moments later, reunite in a blinding spark a mile or more in length and with a mighty concussion.

Atmospheric Electricity is a worthy member of the Monograph Series on Physical Subjects. The author appears to have chosen his abstracted material very wisely and the reader, when finished, has received a coherent and well balanced picture of the whole subject.

T. K. CLEVELAND.

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CURRENT TOPICS.

Sacrificing Gooseberries for Pines.—(U. S. D. A. Clip Sheet No. 803.) In the fight against the ravages of the white-pine blister rust, owners of timber and wood lots faced one of those puzzling conditions in which one kind of plant is deadly to another entirely dissimilar plant. The barberry is deadly to wheat; the cedar menaces the apple; and the white pine cannot live as a neighbor of the gooseberry and currant plants.

The blister rust is a fungous disease which is destructive to white pines of all sizes. Its effect is particularly noticeable in preventing young seedlings and saplings from reaching commercial size. The spores produced on a white pine will not infect other white pines, but they will develop a rust on the leaves of currants and gooseberries, both wild and cultivated. It is on these plants that spores are produced which can infect the white pines. In New Hampshire particularly, a thorough attempt has been made to eradicate, in all forest areas, the bushes of the gooseberry and currant. A single eradication will protect the pines for 5 to 10 years. Continued eradication should not add more than approximately $1 a thousand feet to the cost of producing white pine lumber.

C.

Research for the Farmer's Sake.—The farming industry also has its research laboratories in the shape of the Experiment Stations of the U. S. Department of Agriculture. More than ever, the various stations curtailed their building programs this past year and devoted a corresponding larger share of their appropriations to meeting the pressing demands for service to the farmers. There follows a partial list of the several State Experiment Stations and their recent accomplishments.

Arkansas found that too much manganese in some soils injures rice, but that lime corrects this condition.

The Nevada and Utah stations have made snow surveys as a guide to estimating the water available for irrigation.

The Montana station has specialized in wheat breeding and more than 90 per cent. of the wheat planted is of the varieties recommended on the basis of comparative tests. Two new varieties, Karmont and Yogo, have distinctive merits.

The Colorado station developed the Peachblow and Russet Burbank potatoes.

The Minnesota station, several years ago, bred the Latham raspberry, and has now surpassed the earlier favorite with a new variety, Chief.

New York, Wisconsin and Pennsylvania stations have been particularly successful in breeding disease resistant cabbages.

The Texas station, by crossing northern sweet corn and the native field corn, has developed a sweet corn which does well in the South.

The South Carolina station showed farmers how to use tobacco barns for curing and storing sweet potatoes, a practical economy.

West Virginia has studied the effects of a soybean crop on the crop to follow and worked out harvesting and plowing schedules for best results.

The Kentucky station traced many "clover failures" to use of poorly adapted seed and advises planting home-grown strains.

The Massachusetts station has studied intensely the characteristics of young apple and pear trees so the different varieties may be distinguished readily while still in the nursery rows.

Washington has worked out the best combinations for interplanting of sweet cherries, which require cross fertilization.

Kansas and Nebraska report material progress in breeding wheat that will not be injured by the Hessian fly. Illinois and Ohio stations are coöperating in breeding strains of corn resistant to attack by the European corn borer.

The Iowa experiment station developed a poison formula for grasshoppers, and airplanes distributed the poison bait.

The Vermont station is making valuable studies in the artificial drying of immature grass to preserve feed values and several stations are experimenting with the bruising of green foliage to hasten drying. Kansas discovers that adding finely ground limestone to silage improves it and reduces the requirement for legume hay in the ration of young cattle.

C.

Who Uses the Weather Bureau?—By order of President Roosevelt on July 31, 1933, there was created the Science Advisory Board which acts under the jurisdiction of the National Academy of Sciences and the National Research Council. A special committee on the Weather Bureau has been appointed by this Board and a preliminary report of the committee's findings and recommendations has been submitted. It is estimated that the U. S. Weather Bureau's forecasting service probably touches directly the immediate

needs of more people in this country than do all other Federal services combined, with the single exception of the postal service. There is little general realization of the extent to which this forecasting service involves the personal interest of the whole population. Take, for example, the significance of a single temperature forecast in the life of some city. With notice of an approaching cold wave greenhouses are closed and boilers fired. Preparations are made at once by heating and lighting plants, whether gas, electric, steam or hot water, to meet the increased demands that will follow. Fire hydrants, exposed mains and general plumbing are protected. Gasoline engines are drained and automobile water-cooling systems are protected by the use of antifreeze solutions. Work in concrete is stopped. Street railway companies arrange for more heat in their cars. Merchants direct their advertizing and attention largely to cold weather articles. Oyster dealers increase their reserve stocks. Ice factories reduce their output. The dredging of sand and gravel ceases, and iron ore piled for shipment is placed in the holds of vessels, to prevent the wet masses from freezing solid. Charity organizations prepare to meet increased demands for food and fuel and thus minimize suffering among the poor.

Nor is that all: Agricultural forecasts as to the dangers from rain, drought and frosts result in the saving of crops such as hay, corn, fruits and vegetables. Every increase in the reliability of these forecasts runs into large figures when expressed in dollars. In the citrus-fruit districts of California, fruit to the value of $14,000,000 was saved by taking advantage of the Weather Bureau's cold wave warning.

The railway and transportation companies make continued use of the forecasts in their shipments. Perishable products are protected against temperature extremes by refrigeration or heating as conditions may require. Frequently shipments of perishable goods are accelerated; at other times, goods en route are run into roundhouses for protection. Often, an advance notice of a cold wave will hold up a shipment liable to damage through exposure. Bananas, in particular, require very careful handling and must be kept at a temperature of 58° to 65° F. because too low a temperature leads to deterioration in quality while one too high will produce over-ripening.

The River and Floods Division saves millions of dollars worth of property and human lives by the hundreds through the issue of timely warnings. Measurements of precipitation in the drainage basins of streams and observations of the height of water on gauges placed at strategic points are collected by telegraph or telephone from about 900 substations and serve as the basis for warnings of floods.

Issue of such warnings is followed by the removal of stock, harvested crops, and other property from bottom lands, and by a general exodus of the inhabitants of the country where overflows endanger human life. Large freight movements by water often are contingent to a slight rise in the river level; lumbermen profit through advance information on flood conditions which will aid stream-driving of their logs.

The Weather Bureau's service to Marine Navigation is of scarcely less importance than to internal commerce. Storm warnings are displayed at more than 400 points along the Atlantic, Pacific and Gulf coasts and the shores of the Great Lakes. So nearly perfect has this service become that for years few storms of marked danger to maritime interests have occurred for which ample warnings have not been issued from 12 to 24 hours in advance. Reports from the West Indies enable the Bureau to forecast with great accuracy the approach of those destructive hurricanes which, during the period from June to November, are likely to sweep the Gulf and Atlantic Coasts. Warnings displayed for a single hurricane are known to have detained in port vessels with cargoes valued at over $30,000,000.

The Climatological Service of the Weather Bureau is one of the most extraordinary services ever developed anywhere and probably nets the public more per dollar expended than any Goverment service in the world, inasmuch as practically all of this work is done by 4,500 unpaid "coöperative" observers to whom the Bureau has furnished rain gauges and thermometers. These data, so extensively accumulated, form the basis of a country-wide climatological survey which is of immense value to the engineer in his work in irrigation, hydraulic engineering and in the vast task of planning water supply systems.

Last but not least is the service of the Weather Bureau to Aeronautics. This branch is relatively new but has developed rapidly as is attested by the fact that the Bureau's aerological division is already its largest service. At this time, the Bureau is planning to adopt still newer methods of air analysis with view to improving the service many fold.

C.

Chemistry in 1933.—(*Science Service.*) The production of "heavy" water was an outstanding achievement. This water contains hydrogen weighing twice as much as the ordinary kind and has a molecular weight of 20 instead of 18. Heavy water prevents the sprouting of tobacco seeds; kills tadpoles, guppy fish and worms.

A commercially feasible non-poisonous copper plating bath has

been developed by Fink and Wong. This will replace the cyanide bath now commonly used for copper plating of steel.

Two new isotopes of mercury were discovered by Prof. F. W. Aston, Cambridge University, England.

King Tut's purple surface films on gold were proved to be due to the presence of iron in the gold.

Maleic acid, synthetic, will keep edible fats and oils from becoming rancid.

Fink has used the electric current to remove salt crusts from antique Greek pottery vases.

Tricalcium phosphate will prevent sugar and salt from caking.

Sweet potato starch makes a satisfactory sizing for cotton yarn.

A new type of sulfur recovered from coke-oven gas by liquid purification is an effective fungicide, insecticide and soil conditioner.

A new method of producing solid carbon dioxide (dry ice) from gas mixtures containing only 10 per cent. or less of the carbon dioxide was reported.

Iowa State College reports a new fermentation to produce butylene glycol from surplus farm products.

Stone was made artificially by processes probably duplicating those of nature.

Diazodinitrophenol may be used effectively to initiate the detonation of high explosives such as dynamite or TNT.

A new selenium insecticide for the control of the red spider was reported.

A new process for canning tomato juice insures the quick removal of oxygen and preserves the vitamin C content.

It was demonstrated that acetamide, made from acetic acid and ammonia, has a wider range of solvent power than any other unknown substance.

A new and very sensitive test for lead consists of the reddening of a greenish solution of the aniline dye, diphenyl-thio-carbazone.

A growth-stimulating "pantothenic" acid was found in many different kinds of plants and animals.

American-grown rubber from guayule shrub was given commercial tests in automobile tires and tubes.

Sound vibrations far above the audible pitch were found to coagulate proteins, crack vegetable oils, break down ethyl acetate to produce acetic acid and decompose starch to produce glucose.

Jones, a Harvard chemist, has developed a chemically treated cloth which keeps tarnish off silverware wrapped in it.

Paper was made commercially from young Southern pine and regular editions of nine Georgia newspapers were printed on it.

The General Electric Company has developed a mercury-vapor

detector which will detect one part mercury in 100 million parts of atmosphere.

C.

Physics in 1933.—(*Science Service.*) The lowest temperature ever produced and measured, eighty-five thousandths of a degree above the absolute zero, was achieved at the University of Leyden by the adiabatic demagnetization of paramagnetic salts.

The existence of the positive electron was confirmed.

The conversion of energy into mass was demonstrated in the bombardment of lithium by helium nuclei.

It was suggested that cosmic space between the galaxies is filled with high energy positrons which constitute an appreciable fraction of the total mass of the universe.

"Positive" X-rays were produced by impinging positively charged ions upon a metal target.

Boron atoms were smashed when bombarded with hydrogen nuclei; neon was smashed by speeding neutrons and lithium atoms were disintegrated by bombardment with protons.

Deutons, the nuclei of heavy weight hydrogen, have been employed to knock protons out of carbon, and neutrons out of beryllium and lithium.

It seems to be agreed generally that cosmic rays are discrete particles and not merely electromagnetic impulses. Just what kind of particles compose cosmic rays, it is not yet agreed.

Cosmic rays that are four times as penetrating as those hitherto known were demonstrated in Germany.

A static or radio impulse that seems to come from the vicinity of the heart of the Milky Way was discovered by Karl G. Jansky, Bell Telephone Laboratories.

X-rays are generated by the passage of a swiftly moving electrified particle through gas, Dr. Gordon L. Locher, Franklin Institute, discovered.

A Van de Graaff 10,000,000 volt direct current electrostatic generator was completed and demonstrated.

Thin films of alkali metals were found to be transparent to ultraviolet light but opaque to visible light while powder films of silver, gold and several other metals were shown to be transparent to infrared or heat rays.

Ultra-short radio waves two meters in length were passed through mountains and curved around the surface of the earth while undamped three-centimeter radio waves were generated and used in high-frequency magnetic and electric experiments.

The iconoscope, a television apparatus without scanning disk or

other moving parts, consisting of multiple light-sensitive photocells played upon by a stream of electrons, was developed by Dr. V. K. Zworykin.

A portable roentgenometer of about fountain pen size was invented for the protection of scientists working with radium and X-rays.

Permanent-magnet alloys of many times the strength of the commonly used tungsten or chrome magnet steels were developed in the General Electric Research Laboratory.

An X-ray unit, as small as practical, has both the Coolidge tube and the high-tension transformer immersed in oil. It is rated at 58,000 volts and 10 milliamperes.

Thompson and Rose have developed very small vacuum tubes for operation with conventional circuits at wave-lengths as short as thirty centimenters.

C.

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